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SURVEYING MANUAL

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PLEASE REMOVE THE ENTIRE CONSTRUCTION SURVEYS SECTION FROM YOUR CONSTRUCTION MANUAL AND PLACE IT IN THIS MANUAL JUST AHEAD OF THE INDEX.

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COVER LETTER

This manual has been compiled to tell Montana Department of Highways field surveying personnel what survey information is required so that their work can be utilized by designers, R/W personnel, inspectors, contractors, etc.

The surveying manual is limited to Montana Department of Highways requirements. Surveying tables and general surveying information are omitted so that the size of the manual can be kept manageable and because this material is covered in numerous copywritten surveying texts. This book is meant to supplement such texts and not to replace them.

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SURVEYING MANUAL

CHAPTER I

PRELIMINARY SURVEYS

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I-10 GROUND CONTROL FOR PHOTOGRAMMETRIC MAPPING

10.00 General

The Department of Highways has in recent years relied, almost exclusively, on photogrammetric methods for conducting preliminary surveys. Aerial photos are used to compile topographic maps from which project alignment studies and earthwork volume estimates are made.

Although aerial photographs are the basic tool used to compile the maps, ground control surveys are still an essential part of the mapping process. These field surveys establish measurements on the ground that control the accuracy of all measurements, horizontal and vertical, that are taken from the maps. They establish elevations for vertical control points and straight line horizontal distances between horizontal control points.

Frequently construction field personnel are called on to make these ground control surveys and it is for this reason that this brief discussion of procedures and requirements is included here.

10.01 Survey Request

When a ground control survey is required, a written request for the survey will be sent to the appropriate Division Construction Section. The survey request will include aerial photos and an autoscreen print showing the general layout of the requested field controls. A pocket stereoscope will be provided to aid in locating the control points and markers.

Each control point will be premarked in the field by the Photogrammetry Unit of the Preconstruction Bureau before the survey is requested. The points may be premarked in the field by survey stakes, railroad spikes, paint marks or concrete nails with washers.

The aerial photos that accompany the survey request will have the approximate photo scale (mapping scale) printed on the back, e.g. 1:2400, 1:3000, 1:6000 etc. The required accuracy of the ground control survey is determined from this scale.

10.02 Elevations - Vertical Controls

Vertical control points will be indicated on the photos by red circles with arrows pointing to them. The points will also be described on the back of the photos where space will be provided to record the ground elevation at each point. A level circuit must be run to establish the elevations of all vertical control points. All level circuits from which control point elevations are established should start from a U.S.G.S. or U.S.C. & G.S. bench mark or from an established line of temporary bench marks (TBM's) that is based on a U.S.G.S. or U.S.C. & G.S. bench mark. The permissible closure for level circuits is based on the physical characteristics of the terrain and on the photo scale which will be printed on the back of the photos. Permissible closures are tabulated in Figure 10-1.

10.03 Horizontal Controls

Horizontal control points will be indicated on the photos by black triangles with arrows pointing to them. The points will also be described on the back of the photos. The ground control survey must establish the straight line horizontal distance between these control points. All distances established by the survey must be recorded on the back of the photos as well as in the survey notes.

Bearings and stationing will not be required for straight lines between control points. Deflection angles between control points will not be required

except as noted below for establishing a distance by open-end traverse.

It is essential that the recorded distances be straight line and, for this reason, if two points are not intervisible double centering or other accepted surveying methods should be used to insure that any necessary intervening points are on the straight line path.

If the terrain prevents practical straight-line chaining, an open-end traverse is acceptable. A sketch of the traverse, showing deflection angles and distances, should accompany the survey notes when they are submitted to Helena. From the sketch and notes the Photogrammetry Unit will submit the necessary data to the Data Processing Section to obtain coordinates and compute the straight-line distance.

All distances should be chained at least twice to establish and insure chaining accuracy. The required chaining accuracy will be based on the photo scale and on the traverse. Chaining tolerances are tabulated in Figure 10-2.

Caution: All of the tolerances listed in this section apply only to photogrammetric mapping. The field control established is not intended for use in construction or other surveys.

When additional information or other tolerances are required, surveying specifications will accompany the survey request.

10.04 Survey Completion

When the survey is completed the survey notes, aerial photos, autoscreen, and stereoscope should all be submitted to the Preconstruction Bureau in Helena.

Remember to obtain permission before entering upon private land. If there are any questions regarding ground control surveys they should be directed to the Photogrammetry Unit in Helena, phone 449-2650.

FIGURE 10-1

LEVEL CLOSURE PER ONE (1) MILE CIRCUIT SHOULD NOT EXCEED :

TERRAIN	Photo Scale 1:2400&1:3000	Photo Scale 1:6000	Photo Scale 1:12000	Photo Scale 1:24000
PRAIRIE & HILLY	0.10 FT.	0.15 FT.	0.20 FT.	0.35 FT.
ROUGH MOUNTAINOUS	0.13 FT.	0.18 FT.	0.25 FT.	0.45 FT.

NOTE: a one (1) mile circuit is one (1) mile in and one (1) mile out.

FIGURE 10-2

MINIMUM ACCURACY OF HORIZONTAL DISTANCES:

METHOD OF MEASUREMENT	Photo Scale 1:2400&1:3000	Photo Scale 1:6000	Photo Scale 1:12000	Photo Scale 1:24000
STRAIGHT LINE CHAINING	1:5500	1:4000	1: 2500	1:1500
CHAINING WITH TRAVERSE	1:7500	1:5500	1:3500	1:2500

NOTE: bearings or stationing are not required.

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LOCATION SURVEYS

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II-20 BASIC SURVEY INFORMATION for ROADWAY LOCATION

20.00 General

This is a comprehensive outline of the basic information that must be gathered by location surveys for the proper planning and design of highway projects. Additional information requirements are presented in other sections of this manual but all general location survey requirements are included here. Figures 20-1 through 20-3 are included as sample note forms; sample cross-section notes can be found in the Construction Survey Section, Chapter III.

20.01 Survey Package

A. Hardshell, Plan

1. Minimum plotted scale 1 in. = 100 ft.; 1 in. = 50 ft. Minimum in Urban Areas.

B. Hardshell, Profile

1. The horizontal scale of the hardshell profile should be the same scale that is used on the hardshell plan. The vertical scale should be exaggerated ten (10) times, i.e.

   Horizontal Scale: 1 in. = 100 ft.

   Vertical Scale: 1 in. = 10 ft.

2. Proposed Grade Line

   a. Historical data on snow conditions, prevailing winds, flood areas, icy road areas, accident areas.

3. Soils Profile - Submitted to Preconstruction by Materials Bureau.

4. Bench Marks.

C. Soils Data

1. Topsoil Availability Form - Submitted to Preconstruction by Materials Bureau.

2. Shrinkage and Swell Factor Recommendations.

D. Local Water Data and/or Geologists Recommendations. (See Chapter II-24, Hydraulics Surveys)

1. Rest areas and weigh stations have to have water available, this information will be furnished by the Core Drill Section prior to location of rest area or weigh station.

E. Existing Drainage and Recommendations

1. Form HYD-1 will be completed for each drainage area over one square mile.

2. Engineers' recommendations are usually adequate for drainage areas less than one square mile.

F. Irrigation and Access Recommendations

G. Telephone and Electrical Services

1. Rest area and weigh station sites.

H. Form HYD-1, "Survey Data for Design of Waterways"

1. For all waterways and drainage areas greater than one square mile.

2. For all irrigation affected by the proposed construction.

I. Survey Notes (See Basic Survey Information Articles 20.02 through 20.08)

20.02 Alignment

A. The alignment for the survey section shall conform to design speeds as set forth in the Road Design Manual. The survey shall be extended a minimum of 500 ft. beyond the beginning and end of the design project for possible connections. If a connection may involve a change in grade and alignment the survey should be extended as much as 1200 ft.

B. On urban projects all curves shall be simple curves.

C. On rural projects all curves 1 degree 30 minutes and sharper shall be spiraled.

20.03 Survey Ties

A. A survey tie to the existing highway with angles, distances, stationing and bearings. (Bearings may be taken from an existing project or in some cases a celestial observation must be made.)

20.04 Section Ties and Land Ties (See also: Right-of-Way Surveys, Ch. II-26)

A. Tie all stone or brass cap survey monuments (Section cor., ¼ cor., 1/16 cor., etc.) to the staked centerline, as per Chapter II-26. All found or re-established monuments shall be recorded as per the "Montana Recordation Act" (RCM 67-2001 through 67-2010), which is copied in its entirety in Section 28.01.

B. Tie all city limits, municipal limits, urban limits, urban extension limits, park boundaries, cemeteries, airports, military reservations, Indian reservations, county lines, state lines, Forest

Service boundaries, subdivision boundaries and private tract ownerships, Mining Claims and Homestead entry surveys.

1. In urban areas, all intersecting dedicated streets, as shown on city addition plats shall be tied to the centerline by station and angle. If a dedicated street has been closed give the date of closure and show where the legal record is. Check survey with city addition plats and if they disagree note why. When staked centerline is adjacent to city limits enough transit ties shall be provided so the limits can be plotted on the hardshell.

C. The location of property is tied either directly or indirectly to corners established or indicated by Government survey. It is therefore essential that land lines be plotted accurately on right-of-way maps. This can only be accomplished if section ties are adequate.

20.05 Railroad Ties

A. Ties shall be made at all changes of alignment, either highway or railroad, where roads are adjacent. P.C. or P.T. stations are preferred with equivalent stationing. Where long stretches of tangent are present additional ties will be required. (R.R. bridges and switch points make good ties.)

B. Section line crossings on the railroad shall be tied to the highway section line tie, if within 300 ft.

C. Whenever ties to railroads are made, R.R. personnel should be called to the project site. If this is not possible a copy of the most current R.R. map must be used to establish railroad stationing.

20.06 Topography

A. Tie all physical features which may influence the negotiation of the R/W taking within the scope of the future construction project.

1. All ties shall be right angle and distance.
2. In urban areas all topog ties shall extend ½ block each side of centerline where practicable.
3. Show type and condition of all physical features (fences, buildings, vaulted sidewalks, project markers, mile posts, R/W monuments, etc.) including trees to be preserved or removed.
4. Show land use (cultivated, irrigated, grazing, parking lots).
5. Note all features that may influence or be affected by the highway construction. This may require a special note (i.e. garage under house).

B. Utility Topography

NOTE: (MAKE A SEPARATE SET OR SETS OF NOTES FOR EACH UTILITY)

1. Power
   a. Location with right angle ties and whether utility is above or below ground.
   b. Centerline X-ing station with angle and distance from ground elevation to utility. (either above or below ground).
   c. Ownership (is the line joint use).
   d. Number of wires, (Phase, Voltage) pole numbers (pole condition), pole class, length, guy wire or guy pole locations.

e. Type of encasement if underground.

2. Telephone and Telegraph

a. Same information as listed under Power Topog (items (a) through (e)).

b. Number of pairs of wires in cable.

3. Natural Gas lines or Petroleum Lines

a. Location with right angle ties and whether utility is above or below ground.

b. Centerline X-ing station with angle and distance from ground elevation to utility either above or below ground.

c. If utility is in proximity of any future channel change get elevation on pipe under present channel.

d. Ownership.

e. Pipe size, material, pressure. Type of carrier (crude, refined products or natural gas, etc.) Valve locations. Depth below natural ground to top of pipe for all lines. Meter locations, conditions and date of utility installations.

f. The information recorded under items (a) through (e) shall include all lead-ins (check vacant lots etc.)

4. Water

a. Location with right angle ties.

b. Centerline X-ing station with angle and distance from ground elevation to top of line.

c. Ownership.

d. Pipe size, material, pressure, condition, (date of installation) fire hydrants, valves and type. Historical elevation of frost

line. Source of water, community, city, private, etc. Information shall be furnished as to owners intention for replacement if these facilities are found to be faulty and should be replaced.

e. Depth below natural ground to top of pipe on all lines.

f. The information recorded under items (a) through (e) shall include all lead-ins.

(Check vacant lots, etc.)

5. Storm Sewers and Sanitary Sewers (See also Chapter II-24, Hydraulics Surveys)

a. Location with right angle ties.

b. Centerline X-ing station with angle tie and distance from centerline ground elevation to top of pipe.

c. Invert elevations on all storm and sanitary sewers will be required.

d. Ownerships.

e. Pipe size, material, condition, date of installation and invert elevations.

(1) Manholes.

(2) Drop inlets.

(3) Outfall lines.

f. The information recorded under items (a) through (e) shall include all lead-ins (check vacant lots, etc.).

g. Urban Projects.

(1) Gutter elevations shall be required on all cross streets for a distance of 1 city block each side of centerline.

h. Information shall be furnished as to owners intentions if facilities are determined to be faulty and should be replaced.

i. On all private sanitary facilities the outfall from the source to the septic tank and drainfield shall be noted and size, condition, material, and elevations shall be shown, also date of installation.

6. Traffic Signals and Street Lights

a. Location and right angle ties.

b. Centerline crossing station with angles, and distance from ground elevation to utility.

c. Power source (underground, overhead).

d. Ownership.

e. Traffic signals (manual or mechanically operated). Type of suspension.

f. Street lights.

(1) Poles - Metal, Wood, condition.

(2) Type of illumination.

7. U.S.A.F. Missile Installation. Always contact U.S.A.F. people for special regulations regarding this equipment.

a. Cable Marker Locations with right angle ties.

b. Centerline X-ing station with angle and distance from ground elevation to cable.

c. Azimuth Marker location with right angle ties. (only when marker is within roadway survey perimeter)

C. Irrigation Topography. (See also: Chapter II-24, Hydraulics Surveys)

1. Location of irrigation system with right angle topog ties.
2. Show location of all irrigation structures, pipes, division boxes, flumes, syphons, pumps, wells, sprinkler heads, etc.
3. Determine source and ownership or ownerships, including number of miners inches allotted to the ditch, and say where you got the information.
   a. The number of miners inches dictate the size of culvert to be provided under our roadway.
4. Invert elevations at all major control points. (Source, Division Boxes, Flumes, etc.)
   a. If irrigation ditch is within limits of X-sections then elevation shall be recorded with X-sections.
5. Type of material ditch is constructed of; Is it lined? Make recommendations.
6. Show dimensions of all structures and type of material used in their construction. Submit pictures of all structures.
7. Condition of all structures is important.
8. Label ditches in system as to type: feeder, lateral, collectors, waste water.

D. Drainage Topography. (See also: Chapter II-24, Hydraulics Surveys)

1. Right angle ties to all natural drainage and structures.
   a. Culverts, bridges, etc.
2. Natural stream courses with local name or designation; with elevations every 50 ft. for a distance of 1500 ft. upstream and downstream.

3. In major, normally dry, wash areas the information in item 2 shall also be required.
4. The size of all drainage areas shall be determined and the method of determining the area shall be listed.
5. Culvert recommendations for all drainage areas shall be made. (Show reason for recommendations and background.)
6. Form HYD-1 shall be completed for all major stream crossing. Give groundline profiles at centerline of roadway and 20 ft. right and 20 ft. left of centerline of roadway for every roadway structure. The profiles should extend beyond the width of the floodplain on both sides of the crossing.

20.07 Levels and Cross-Sections

A. Establish vertical control from known bench mark elevation. (National Geodetic Survey bench marks)
   1. A complete check level circuit is mandatory.
   2. NGS bench mark elevations shall be verified as to the latest datum.
   3. Any discrepancy in bench mark elevations, as determined by check levels, shall be transferred to the beginning or end of the project and shown by an elevation equation.

B. Establish centerline profile elevations at each ground break of centerline and provide iron pin bench marks or anything of a permanent nature at approximately each 10 stations. (10+00, 20+00, 30+00...)

C. Cross-sections shall be taken at each major ground break with sections no further than 100 ft. apart. X-sections shall be extended beyond the

contemplated scope of the construction. (Large cuts, fills, or possible curve projections should be taken into consideration.)

1. All breaks in elevation along the cross section shall be recorded, but no 2 consecutive shots may be more than 25 ft. apart.
2. A X-section shall be taken at each culvert with invert elevations recorded. If a culvert is on a skew, X-section on the skew and record as a culvert section only.
3. When X-sectioning irrigated ground, invert elevations of all ditches shall be recorded as such.
   a. In the X-section notes show a sketch with dimensions of all irrigation ditches at right angles to ditch so capacity can be computed.
4. When centerline crosses a major drainage (drainage area greater than 1 square mile), Form HYD-1 should be completed. (See Chapter II-24, Hydraulics Surveys)
5. When a highway survey runs adjacent to a railroad the X-section at each 500 ft. interval shall be extended over the railroad grade and include base and top of rail elevations.
   a. Invert elevations for all drainage structures under the railroad shall be shown with equivalent stationing. Size and condition shall be noted.
   b. See Figure 20-3.

D. X-Sections in Urban Areas

1. X-Sections shall be taken at all major ground breaks (curb

returns, begin and end) with a maximum of 50 ft. between sections, also at each gutterline and centerline of intersecting streets extending 150 ft. left and right minimum, top of curb elevations shall also be shown. Label section or shots in notes. All X-sections shall extend a minimum of 25 ft. beyond property line where possible.

2. Profile elevations shall be taken each 25 ft. along gutterline, top of curb and back of sidewalk. In addition profile elevations will be required in doorways, private sidewalks, driveways, manholes and drop inlets.

20.08 Miscellaneous Information

A. Urban Surveys

1. List of proposed new curb openings.
2. Copy of city standards.
   a. Curb and gutter.
   b. Concrete sidewalk.
   c. Drop inlets.
   d. Curb returns.
   e. Radii.
   f. Width and placement of sidewalk.
   g. Width of intersecting street where curb is not in place.
3. City Plats
   a. Water lines.
   b. Sewer lines.
   c. Electrical.
   d. Telephone.

e. Natural Gas.

f. Any others when applicable.

B. B.L.M. land survey notes for section ties. The original government land survey notes and resurvey notes are necessary to identify corners and accessaries to the original corners. The Corner Recordation form requires information from the original survey notes.

C. Photographs of anything that may be helpful in making design decisions.

D. Archeological or Paleontological Sites - notify authorities immediately on discovery

1. Graves.
2. Pictographs.
3. Bison Jumps.
4. Camp Sites.
5. Tepee Rings.
6. Fossilized or Skeletal Remains.

E. Historical Information (from local residents and maintenance people)

1. Prevailing winds.
2. Snow condition areas.
3. Flooding areas, icy roads, etc.

a. Item (1) and (2) should be noted on hardshell profile with suggested grade line.

F. Cross Road Survey

1. Complete survey of any major or minor highway that crosses the survey sections, a minimum of 1000 ft. each side.

G. Storm Sewer Survey. (See Chapter II-24, Hydraulics Surveys)

1. After the P.I.H. or when sewer determinations have been made, a complete survey from the project to the outfall shall be made. Angle points only for alignment. (Property ties, etc.)

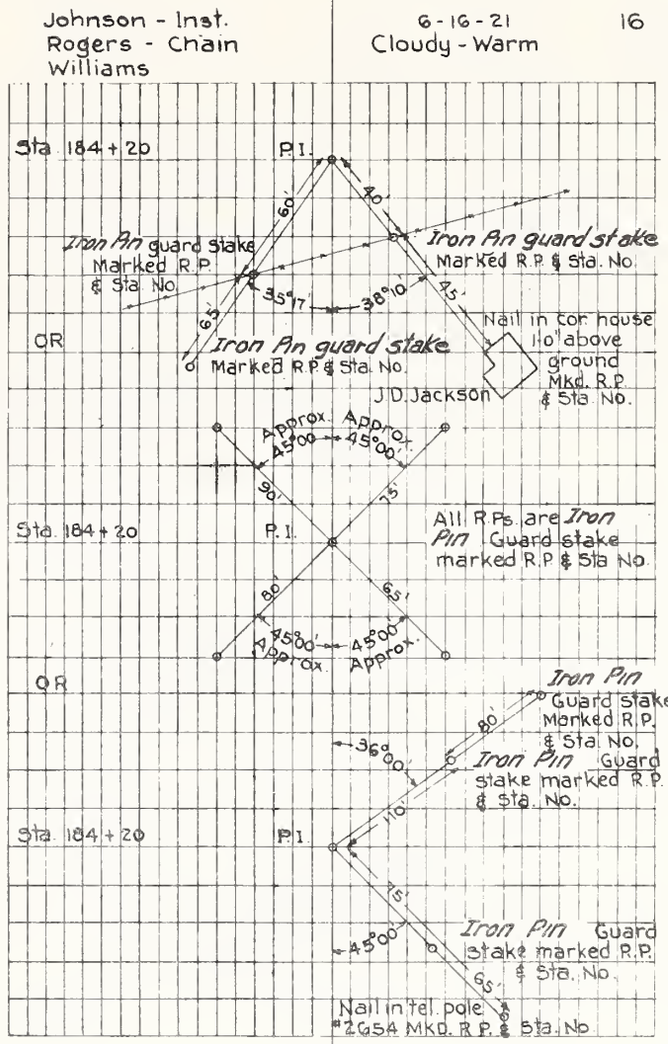
H. Road Approach Information

1. Type of Use.
2. Freqency of Use.
3. Width.
4. Ownership, County Road or Private.
5. Dedicated or not.

FIGURE 20-1

LOCATION TRANSIT NOTES

Station	Point	Defl.	Δ	M. C.	C. C.
EQUATION				S. 26°00'E.	S 06°05'E
187+19.5 AHEAD = 185+20.5 BACK	P.T.	10°05'			
185+00		9°34'			
184+20	P.I.		Δ=20°10' RT.		
			D=5°		
184+00		7°04'	T=203.8'		
			L=403.3'		
183+00		4°34'	R=1146.0'		
182+00		2°04'			
181+17.2	P.C.	0°00'			
				S 46°10'E.	S 26° 15'E.
				P.I. to P.I. 715.0'	
176+00	P.O.T.				


Johnson - Inst.
Rogers - Chain
Williams
6-16-21
Cloudy - Warm
16
Sta. 184+20
P.I.
Iron Pin guard stake Marked R.P. & Sta. No.
Iron Pin guard stake Marked R.P. & Sta. No.
Iron Pin guard stake Marked R.P. & Sta. No.
Nail in cor house 1'0 above ground Mkd. R.P. & Sta. No.
J.D. Jackson
OR
Approx. 45°00'
Approx. 45°00'
Sta. 184+20
P.I.
All R.Ps. are Iron Pin Guard stake marked R.P. & Sta No.
Approx. 45°00'
Approx. 45°00'
OR
Iron Pin Guard Stake Marked R.P. & Sta. No.
Iron Pin Guard stake marked R.P. & Sta. No.
Sta. 184+20
P.I.
Iron Pin Guard stake marked R.P. & Sta. No.
Nail in tel. pole #2654 Mkd. R.P. & Sta. No.

Reference Points at right angles if possible.

Reference Points must be firmly set and well marked so as to be easily found.

Run all curves from Harger and Bonney data. R=5730'

Show detail data in proper column, how curve was staked in field.

Use sufficient space to make notes clear and distinct without crowding.

Curves may be located by deflection angles or tangent offsets.

When the deflection angle is 30° or greater the P.I. may be referenced by two R.Ps. on the back tangent produced ahead or the new tangent produced back. Measure distances to R.Ps.

Show relationship between bearings of survey & bearings of adjoining projects.

FIGURE 20-2

TOPOGRAPHY NOTES

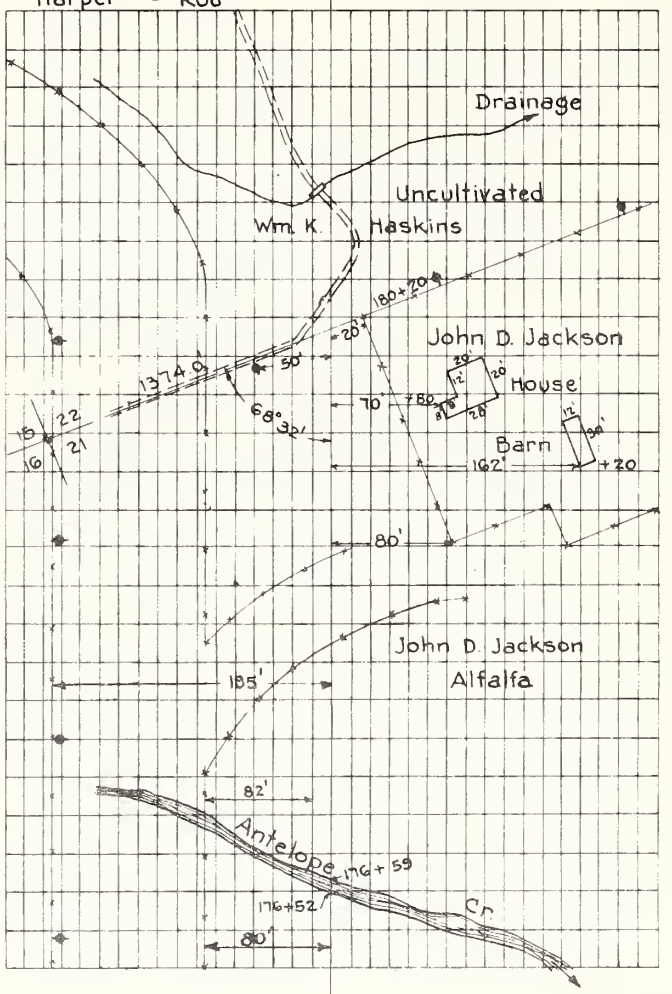
Station	Designation	Classification
182 + 00		
+ 10	36"x 28' C.M. Pipe (Poor) 2-M6 Hdwlls (Poor).	
181 + 00	Drain in place - Remove	
	New 48"x	
+ 40	Old road	
+ 20	Section line	
180 + 00		
179 + 00		
178 + 00		
177 + 00		
+ 59	Top of bank	
+ 55	Creek bed	
+ 52	Top of bank	
176 + 00		

10% Rock

Johnson - Inst.
Rogers - Chain
Williams -
Harper - Rod

6-24-41
Cloudy - Warm

12



Where ties to section lines are made on a curve, same must be taken to semi-tangent and to circular curve.

Designate all structures, both in place and proposed. Irrigation or drainage. Show direction of flow.

For structures in place, be sure to give sizes, type & condition.

In land use, give cultivated, swamp or grazing.

Sketch all topography using direct & ties in feet. Pole lines to be identified as to kind, owner, & no. on poles, no. of wires & clearance wherever line crosses proposed center line. (Clearance is to the lowest wire). Station & Angle. On Power lines - give voltage.

On Form HYD-1 fill in all requested data for all major drainage areas, waterways, and irrigation.

Classification can be covered by giving the percentage of rock.

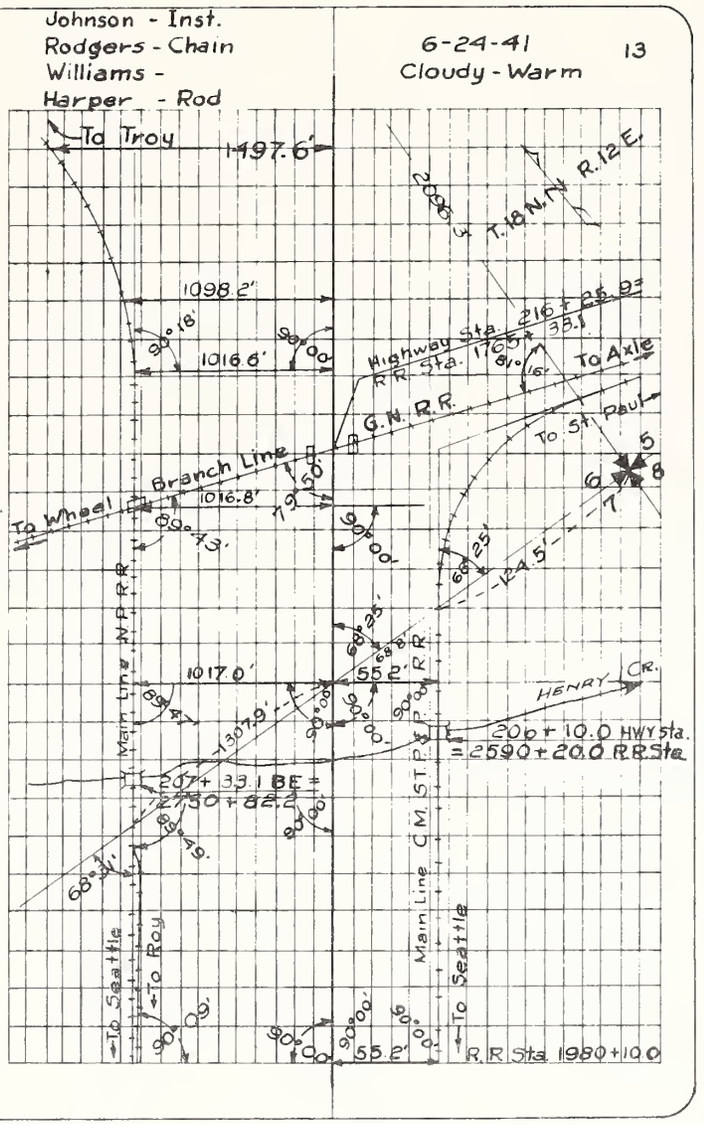
Locate all springs.

Do not crowd notes.

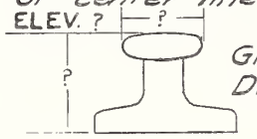
FIGURE 20-3

TOPOGRAPHY NOTES (RAILROAD)

Station		Designation			Classification
224+00.0					
220+00.0					
218+09.0					
215+00.0					
214+67.3 = 2768+16.4 N.P. R.R. Sta = 1436+83.2 G.N. R.R. Sta.					
210+00.0 = 2763+49.1 R.R. Sta.					
C.M. St. P. & P.	75'	Untr.	Tbr.	Pile Bridge On R.R. Rt.	
N.P. R.R.	66.3'	Treated	Tbr.	Pile Bridge On R.R. Lt.	
205+00.0					
200+00.0	1017.9'	Between	℄'s	Highway & R.R. Lt.	



Bridges on R.R. - Give length, water way area, type of bridge, Elevation top of rail, profile of stream or flow line from R.R. to Hwy. ℄, X-Sec. of that area.
Locate all R.R drainage structures, give sizes & Elev. of Invert
Show all rivers, creeks & Irr. Dts.
Make at least two transit ties on each railway tangent on R.R. ℄ within 400' of any Hwy. ℄.
Make sufficient transit ties on curves so that the ℄'s can be accurately plotted.
Give equivalent stationing of Hwy. to Ry. either by tying to a permanent Ry culvert, bridge or stationing marker; or by measuring distance along track from transit tie to permanent Ry. culvert or bridge.
At every location where Ry. ℄ Hwy. are within 400' of each other, extend not less than two X-section from Hwy. ℄ across Ry. Emb.
When Hwy. is located along Ry. for considerable distance extend X-section across Ry. at Max. intervals of 500'.
Note the location of Ry. telephone or telegraph or power poles and number of wires, if between Hwy. and Ry., tie in with survey data.
Where Ry. crosses Hwy. show Hwy. Sta. & R.R. Sta., angle and on Ry. curve show chord Min. of 200' each side of center line.



Give Rail Dimensions.

II-22 TOPOGRAPHIC SURVEYS FOR LIGHTING & SIGNALIZATION

22.00 Introduction

The following is a detailed list of the requirements for topographic surveys for the planning and design of lighting and/or signalization projects.

22.01 Lighting Projects

A. Location of all permanent objects (poles, signs, pull boxes, fire hydrants, posts, buildings, trees, shrubs, hedges, etc.) along the roadway between the curb and right-or-way, or at least 20 ft. from the face of curb.

B. Width of roadway from curb face to curb face, or edge-of-pavement to edge-of-pavement, and width of sidewalks and strip between curb face and sidewalk, including side streets.

C. Location and width of curb openings along roadway, including down side streets for at least 20 ft.

D. Locations, number, and type of overhead lines crossing the roadway and those running parallel to the roadway, including minimum ground clearance in both cases. The horizontal distance from the face-of-curb to the first and last lines when there are several lines spaced horizontally and running parallel to the roadway.

E. Note equipment mounted on light poles (control boxes, meters, signs, fire alarm boxes, etc.) and whether poles are metal or wood.

F. Note location of power poles near intersections that may possibly be used as service points.

G. Note condition of roadway and sidewalks.

H. Right-of-way widths, including side streets.

I. Overhanging encroachments (awnings, marquee, etc.)

J. All underground utilities (gas lines, sewer lines, water lines, telephone cables, etc.) as outlined in the previous chapter on Location Surveys.

22.02 Signal Projects

The same information is needed for signalization projects as is listed above for lighting projects, except that the information is only required for 100 ft. on all approaches to the intersection (s) to be signalized.

II-23 GEOLOGICAL SURVEYS

23.00 General

Surveys are usually required by the Geology Section because of geologic conditions that exist near a roadway or because a road is to be built in a geologically hazardous area; therefore, these surveys should be tied to existing surveys for the roadway.

Surveys of landslides, gravel pits, and quarries can be enhanced by use of photographs. Several photos should be taken, from different angles, showing different aspects of the area. The date, time, and orientation should be documented on the back of each photo.

Notes on types of material, general description of the terrain, and any other information that may be of use to the Geology Section, will be of benefit to the survey.

If a question arises about what is required by any survey requested by the Geology Section, the section should be contacted as soon as possible to insure that the right information is obtained. This will lessen the chance of delays being caused by having to resurvey.

23.01 Gravel Pits and Quarries

A closed traverse around a pit or quarry and cross sections of the pit (quarry) are necessary to determine the volume of material available. Any exploration holes or pits in the quarry must also be tied into the survey and the overall survey tied, if possible, to the roadway centerline. If this is not practicable then the survey should be tied to a section corner, quarter corner, or other recognized reference.

23.02 Landslides

Knowledge of rate of movement and total movement (vertical and horizontal), are often of vital interest to a geologist in studying and correcting a landslide condition. Often it may be some time before a geologist can get to a slide, and survey control may have to be established before he arrives.

A minimum control will require at least one line established perpendicular to the main movement of the slide and one line parallel to the main movement through the center of the slide, with elevations usually established on all points. The line perpendicular to the movement should consist, at a minimum, of a point on each side and one point in the center of the slide. The line parallel to the movement should consist, at a minimum, of one point above, one point below, and one point in the center of the slide. In all cases the number of lines and the number of points should be sufficient to give a true picture of the slide movement.

The method just described is the fastest and the easiest from which to discern movement, as straight lines are used. However, triangulation is very helpful in determining the amount and direction of movement, and should be considered when the survey of the slide is planned.

The thoroughness of the survey will depend on the accessability of the slide, its size, and possible danger caused by the slide. Cross sections and long sections of the slide are also necessary to help establish the depth of the slide and to fully analyze the condition.

Survey notes for landslides can be enhanced by noting the general terrain (mountain, cut slopes, embankment, etc.), speed of failure (creep type failure or sudden failure), whether there was any advanced warning of failure, the type of material, and the type and degree of slope in which the failure occurred.

Photographs are of great value when used with survey notes. Comments on the weather preceeding and subsequent to the failure should be noted, along with any other unusual conditions. The above data may be the only source of knowing the original conditions and will greatly aid toward a solution in problem areas.

Miscellaneous surveying on landslides may require surveying in sites of instrumentation and drill holes. These will be handled as explained in the following sections.

23.03 Drill Holes

Drill holes, when possible, should be tied by station and distance, left or right, to the centerline of roadway. If the centerline is not surveyed, a tie to a section corner, quarter corner, bench mark, or other point is acceptable. Elevation is very important in surveys for drill holes because the elevation will reference the subsurface data which will be incorporated into the plans.

Drill holes are often used to emplace various monitoring instruments, these drill holes will require surveying as outlined below.

23.04 Instrumentation

A. Slope Indicators - used in slides or in conjunction with large fills or cuts. These installations provide information on horizontal and vertical movements below the ground surface. The data derived from slope indicators give information on the movement of landslides or impending failure of large fills or cut slopes. A first order survey is required so that when the survey is checked any movement can be readily detected.

B. Settlement Platforms - These are used to detect or monitor vertical movement. Knowing the initial elevation is vital, as subsequent movement is calculated from the changes in elevation of the platform.

C. Piezometers - Piezometers are used to monitor the changes in pore pressure under a fill to indicate reaction of the foundation soils to the embankment loads. As the pressure is a function of the amount of material over the piezometer head, the elevation of the head is necessary, plus periodic levels along the fill so that total overburden can be calculated.

D. General - Instrumentation available for use in road work is constantly being improved. As development continues, the surveying needed for proper utilization changes. As requirements change, the Geology Section will submit amendments to this section of the surveying manual.

II-24 HYDRAULICS SURVEYS

24.00 Introduction

No matter how precise the hydrology of a watershed may be established and exacting the hydraulic computations, the end result will be no better than the survey. This does not mean the survey should be exacting to the nearest hundredth of an inch - although reasonable accuracy is necessary, but that the survey portrays the true situation. It is to this latter item - the true situation - that this chapter is directed.

The object of this Chapter is to give the survey personnel guide lines as to what information is needed and why it is needed. All hydraulic surveys are different and many times items will be encountered that are not discussed in this manual. The survey personnel should always feel free to phone the Hydraulic Unit and discuss with them what information should be submitted for a particular hydraulic site.

The old saying, "A picture is worth a thousand words" is doubly true when discussing a hydraulic survey. The need for adequate photographs cannot be over emphasized. A great deal of information can be submitted in photographs. Photographs should always be well labeled on the back.

The survey personnel should always make any comments or recommendations that they feel might be pertinent to the hydraulic design. A short discussion of the hydraulic history of a site is often helpful in the hydraulic design.

24.01 Survey Data for Design of Waterways

A. General

To insure that all of the watershed data is submitted, Form HYD-1

is provided to record the basic data for a watershed. Other pertinent data should be submitted with Form HYD-1 on separate sheets. This form shall be completed by the survey personnel for all stream crossings with drainage areas of one square mile or more, except that, Section 8 of the form need not be completed for stream crossings with drainage areas less than five square miles unless a bridge will be required at the crossing. Form HYD-1 should be filled out in ink or filmograph (plastic) lead to provide a more permanent record of the survey data.

The following paragraphs list and describe the watershed data required by Form HYD-1. The data for each item required on the form shall be placed in the appropriate blank completely and accurately. Additional sheets should be used when sufficient space is not available on the form. All supporting documents, such as survey notes, photographs, etc. shall be submitted with Form HYD-1. All photographs should be labeled, dated, and referenced on the back of the photograph. Photographs should not be taken when the stream is frozen or the ground is covered with ice or snow, unless such conditions portray a situation that the surveyor feels should be brought to the attention of the Hydraulics Unit.

Some of the information requested will not be readily available and will require some research or consultation with appropriate people to obtain the required information.

B. Watershed Data

This section contains means for the survey personnel to describe watersheds in terms that will be usable by the designer. Other items such as debris and ice are included since they have a direct bearing on the

type of structure to be selected.

1. Area

The total drainage area of the watershed should be estimated to determine whether Form HYD-1 should be completed. If the total drainage area is near one square mile, or, if the drainage area cannot be determined, then the form should be filled out completely.

There are several methods for estimating the drainage area. The easiest is the visual estimate. This method should be used only for small drainage areas which can be totally viewed.

Maps and aerial photos are by far the quickest method for determining drainage areas. County maps provide a doubtful degree of accuracy except on the larger drainage areas. The county maps do have an advantage in that they provide state wide coverage. The Army Map Service series of contour maps with a scale of 1:250,000 and contour interval of 200 ft., can be used for drainage areas down to several square miles. These maps also provide statewide coverage. The U.S.G.S. "quad sheets" with scales of 1:250,000 (150 ft. contour interval), 1:62,500 (40 ft. contour interval), and 1:24,000 (20 ft. contour interval) provide a much more accurate area determination, but coverage is not statewide. When ever aerial photos are available, they will be found to be invaluable for estimating drainage areas.

Sometimes there will be parts of the total drainage area that do not contribute to the run off from the basin. These may be low areas, swamps, lakes, etc. These areas should be determined as accurately as possible and the information provided on Form HYD-1 so it may be compensated for. If this area is significant, an explanation should be

attached to the form.

2. Land Use and Cover

Land use and vegetative cover have a great deal of affect on the run off from a drainage area. Therefore, estimates of the percentages of the various types of use and cover should be given. The percent of forest cover is an important parameter in determining run off in many parts of the State. Following is a list of other types of cover that might be given consideration:

Forest Lands

Row Crops

Range Lands

Grain

Pasture

Permanent Meadow

Farmsteads

Residential Areas

Commercial Areas

Any other type of land cover or use that may be significant should be given, also.

On smaller watersheds, the various percentages can be visually estimated. If there is likely to be a change in land use for a portion of the drainage area at some time in the future, some mention should be made of the change.

3. Debris

Flood flow reaching a culvert or bridge nearly always carries

debris which may be either floating material, material heavier than water, or a combination of both. Debris must be considered in the hydraulic design because it can be deposited at the culvert or bridge entrance, thus impairing its operation. A thorough study of the extent and type of the debris orginating in the drainage basin is essential for proper design.

The type of debris has been classified into the following groups:

1. Very light debris or no debris
2. Light debris - small limbs or sticks, orchard pruning, and rubbish
3. Medium debris - limbs or large sticks
4. Heavy debris - logs or trees
5. Other - city trash, old car bodies, etc.

The group that best exemplifies the debris from the drainage basin should be indicated on Form HYD-1. If the "other" classification is checked a short discussion of what the debris consists of should be attached. Possible future changes in the type of debris that might result from changes in land use in the drainage basin should also be noted. As an example, logging in a previously virgin area could change the nature of the debris problem from one of "medium debris" to "heavy debris".

An estimate of the quantity as well as the type of debris is needed by the designer so that adequate debris storage can be provided. Information on the types and quantities of debris resulting from past floods can be an invaluable guide in selection of the type of debris

control structure. Such information may be secured from maintenance personnel, from inhabitants of the immediate area or by personal observation.

4. Ice

Ice conditions, like debris, have a direct bearing on the type of structure and substructure used. Ice can cause damage at hydraulic structures in two ways: (1) ice can exert high forces or pressures causing a structure to buckle or collapse, either by thermal expansion during freezing or by impact of large chunks of ice on the structure at high velocities. (2) ice can plug the waterway causing flooding to upstream property and possible damage to the structure.

The potential for ice damage at a crossing should be determined and indicated on Form HYD-1 as Light, Moderate, or Severe. If it is determined that the ice damage could be severe a discussion of the type of damage and how it could be caused should be attached. Maintenance personnel and local residents may aid in establishing whether or not there is a potential ice problem.

5. Unusual Watershed Characteristics

Sometimes a watershed is encountered whose characteristics differ significantly from those expected for watersheds in that vicinity. When an unusual characteristic is encountered it will be the responsibility of the survey personnel to write a detailed description of the unusual feature and attach it to Form HYD-1. Following is a brief discussion of several unusual characteristics that might be encountered and what information should be given about them.

It is difficult to make run-off predictions for streams that get a great deal of their flow from springs. When such streams are encountered, the location of the springs within the Drainage Basin and an estimate of their flow should be given. Because of the difficulty in predicting run-offs for such a stream, description of other crossings both upstream and downstream should be given. The following information should be given in the description: size of pipe or area under bridge, type of entrance, length of pipe, type of pipe, height of fill, and historical adequacy.

Dams can also affect the run-off and complicate run-off predictions. They should be adequately described so their affect can be considered. Large government dams need not be described because a record of these dams are readily available. The small stock dams are of primary concern. The description of the dam should include the name of the owner and builder, the type of material (earth or concrete), height, location in drainage basin, approximate area of the reservoir when full, and a detailed description of the spillway and outlet control works.

6. Water Surface Elevations

The water surface elevations should be measured at the centerline of the survey. If an existing structure makes it impossible to measure the elevations at centerline, they should be measured at the upstream end or edge of the structure and a note added to Form HYD-1 indicating where they were taken.

The elevation of the water surface on the date of survey should be taken and shown on all of the cross sections in Section 6 of the form.

The low water elevation should be the approximate elevation of the water surface at its lowest point during an average year. If the stream goes dry at some time during the average year, it should be so indicated. Local residents might be able to help in establishing a low water elevation.

The high water elevation requested on Form HYD-1 is the historic high water elevation. This elevation can be established in several ways. There may be visual signs such as drift lines or water stains that will indicate the high water mark. Local residents, Highway Department maintenance personnel, County Commissioners, and county road foremen (on secondary projects) will many times remember how high the water got at certain points and may help establish the high water elevation. Written records, such as newspaper stories, may also help establish the high water elevation. The date and the cause of the high water should be given if they can be determined.

Establishing the location, nature and elevation at which damage would occur from upstream flooding is an extremely important part of this section. Some sites may have several damage elevations. The elevation, and a brief description of the damage should be located in Section 8 (or Section 5, if the scale is better) of Form HYD-1.

If the stream being crossed contains game fish which must pass through the structure to spawn or for some other reason, this should be indicated.

C. Existing Structures

The purpose of the existing structure information is to aid in estab-

lishing the size of the proposed structure. The capacity of the old structure together with the knowledge of how well it has carried past floods will aid in determining the size of the new structure. The existing structure may also influence the hydraulics at the proposed crossing if it is left in place.

The historical adequacy of the existing structure and the high water elevation can be determined by visual marks, by talking to local residents, and in some cases by old newspaper accounts. The high water elevation should be measured at the upstream edge of the structure.

D. Erosion and Geology Data

The information requested in the Erosion and Geology Section is self explanatory and will be used to determine what type of bank protection will be used and when to use it. If the scour is very severe, a short description giving depth, etc. should be attached to the form.

The channel stability information refers to the channel bottom and not the banks. A degrading channel is one in which the bottom is being eroded away and is lowering. An agrading channel is one in which the water is depositing material and is building up.

The chemical properties of the soil and water will be used to determine whether steel or concrete pipe culverts will be used. The lab should be consulted when determining the chemical properties.

E. Location Sketch

The purpose of the location sketch is to show the general topography of the crossing area. This sketch should show the stream meander

and the location of all existing roadways, roadway structures and buildings in the area plus the locations of channel cross sections plotted in Section 6.

F. Cross Sections

The channel cross sections are the most important part of the survey data collected. Care should be taken to see that they accurately describe the channel. A minimum of three cross sections is required for every crossing and some of the more complex crossings will require more. If there is not enough room provided on Form HYD-1 for all of the cross sections, the extra ones should be plotted on an additional sheet of cross section paper and attached to the form. The location of each section taken should be indicated in Sections 5 and 8.

NOTE: (THE BRIDGE DESIGN SECTION REQUIRES GROUNDLINE PROFILES AT CENTERLINE OF ROADWAY AND 20 FT. RIGHT AND 20 FT. LEFT OF CENTERLINE OF ROADWAY FOR EVERY ROADWAY STRUCTURE. THE PROFILES SHOULD EXTEND BEYOND THE FLOOD PLAIN ON BOTH APPROACHES TO ALL CROSSINGS WHERE A BRIDGE MAY BE REQUIRED. THEY SHOULD BE SHOWN IN THE NOTES ONLY AND SHOULD NOT BE PLOTTED ON FORM HYD-1.

Each section should be taken normal to the direction of flow. Since the area of flow is determined from the cross sections, an improperly oriented section may produce a large error. Each section should be extended far enough to extend above the maximum possible flood. Sometimes this will require a cross section of a very wide flood plain but this is information that is required and must be taken.

Another very important feature of a cross section is the location and

classification of vegetation and streambed material. Methods of recording this information are indicated on the sample surveys at the end of this section.

When an extensive flood plain is encountered, it may be necessary to plot the entire cross section using a small scale and replot the low water portion of the channel to a larger scale so the more important features of this portion of the channel can be shown in more detail. An example of this method is shown in Example 3 at the end of this section.

A minimum of three cross sections is required at every crossing. Sections are required at each of the approximate upstream and downstream construction limits and a typical section of the downstream channel is required. Consideration should be given to area, shape, channel material and vegetation when choosing the location of the downstream typical section.

In addition to these required cross sections, other cross sections may be required to adequately describe the channel. If there is an existing bridge in place, a cross section should be taken beneath it. If there are any significant constrictions either upstream or downstream from the crossing, they should be defined with a cross section. Any major changes in channel shape or area should also be cross sectioned.

Photographs of each cross section should be taken. Each should be well labeled to identify it. The photos should be taken at a time when the vegetation and channel will not be obscured by snow or ice.

G. Profiles

The profiles are needed to determine the energy gradient of the channel and to aid in establishing the invert elevations of the required structures. Two profiles are needed. The required profiles are: (1) a profile of the thalweg (a line describing the lowest point in the channel) and (2) a profile of the water surface. The thalweg profile of such rivers as the Missouri, Yellowstone, and Clark Fork are very difficult and may be omitted if an adequate water surface profile is taken.

The profiles should extend 1500 ft. upstream and downstream from the proposed crossing. The profiles should be extended when necessary to incorporate ties to confluences with other streams, dams, or any other feature that could influence the proposed construction.

Whenever it is anticipated that a culvert will be necessary and that it will not be placed in the existing channel, a profile should be taken along the centerline of the proposed pipe. Whenever a channel change is necessary, a profile should also be provided along the centerline of the proposed channel changes. These profiles should be tied into the existing channel on both ends.

H. Plan

The plan section serves two purposes: (1) the Hydraulics Unit uses it to determine some of the hydraulic features of the crossing and (2) the Bridge Section uses it to locate new bridge ends when a bridge is required.

Section 8 need not be completed for drainage areas less than five square miles unless a bridge will be required at the crossing. Refer to the previous note for bridge design requirements.

The plan should show the detailed topography and contours of the immediate crossing area. The contours provide the most important information in this section. The contour interval should be chosen carefully so that good elevation detail is shown and so the plan does not become cluttered. The horizontal scale should be chosen as large as possible but small enough that all of the topography will still fit in the space provided.

24.02 Irrigation Surveys

A. The Survey

Anytime a proposed construction project will cross or in any way affect an irrigation ditch, an irrigation survey should be made. Form HYD-1 should be filled out completely with the exception of Section 1, Watershed Data. The watershed data does not apply to irrigation crossing.

Section 2, Existing Structure, and Section 3, Erosion and Geology Data should be completed in the same manner as for a natural waterway.

Much of the information requested in Section 4 will require some research but it is extremely important and must be completely filled in. Because the ditch company must always be contacted for approval of plans, the name of the ditch and the name and address of the owner should be provided. Many times a government agency such as the U.S. Bureau of Reclamation, U.S. Bureau of Indian Affairs, or the Montana Department of Conservation and Water Resources will have control and jurisdiction over an irrigation district. If this is the case, the name of the agency concerned should also be provided.

The hydraulic data requested in Section 4 such as capacity, slope, depth, and ditch dimensions should be those provided by the ditch company and not the surveyed values. If the ditch also carries flood water, this

should be indicated and an explanation attached.

The location sketch should contain all of the information required for natural drainages plus a layout of the entire irrigation system within the scope of the sketch. All main canals, laterals and field ditches and their direction of flow should be shown. All hydraulic structures such as pipes, flumes, turnouts, drops, checks and headgates should be located. The invert elevations of these structures should be indicated. Note any washout area.

The cross sections taken for irrigation should be typical sections that will represent a section of the ditch. Anytime any of the channel characteristics, such as shape, area, vegetation and channel materials change, then another cross section should be taken. The location of each section and the reach of the ditch for which each section is typical should be indicated in Sections 5 and 8. Vegetation and channel bottom material should be accurately described so the channel roughness can be determined. Photographs of each typical section should be submitted.

A profile of the invert and a profile of the water surface should be provided for each ditch. Slopes as flat as .0002 ft./ft. are not unusual for irrigation ditches so it may be necessary to extend the profiles a long ways upstream and measure elevations to hundredths of a foot in order to establish the slope. The invert elevations of structures such as turnouts, checks, etc. should be recorded. If a channel change will be required, a profile should be run along the approximate channel change line.

The Plan (Section 8) should be completed in the same manner as for natural watersheds. However, the contours need not be drawn for irrigation

crossings unless the crossing is so complex that it cannot be easily represented by a couple of cross sections.

Where the irrigation systems are complex and are to be involved with a revamping or possibly relocation of the irrigation, the irrigation ditches and facilities should be traced out far enough so that an adequate design can be made.

24.03 Water Supply

The need for water for irrigation and domestic purposes is becoming greater as more landscaping projects and rest areas are built. The primary sources of water for these projects are wells and springs. Good information is needed to efficiently develop these sources.

A. Water Wells

The well is the main source of water for the majority of landscaping and rest area projects, and weigh stations. A great deal of information is required to design the pumping and distribution systems and to efficiently develop the well. The required information is requested on Form HYD-2. It will be the responsibility of the Core Drill Section to see that the form is properly filled out and submitted to the Preconstruction Section.

1. The Well Information requested on Form HYD-2 will provide all the necessary information about the well. The size and type of casing, size and location of perforations, and size and location of screens, if they are used, should be indicated on the form. Many times the casing and screens are pulled after test pumping and the contractor is required to redrill the well under the construction contract. If the casing and screens were pulled, this should be indicated on Form HYD-2. The elevation at the top of the well

should be the ground elevation at the well and should serve as the datum for all measurements to the water level and bottom of the well.

2. The Water Information that is requested on Form HYD-2, is extremely important and should be recorded accurately and completely. The value of a pumping test can be increased greatly with a little additional effort, time, and expense. Never be afraid to make too many measurements or observations. The depth of static water level should be measured before the test pumping starts and should be measured from the top of well datum elevation. The type and size of the test pump is used in analyzing the pumping test data.

The date on which the test pumping is done and the question about the amount of fluctuation in the water table are also important and deserve some time. If a pump test is run in May when the water table is high and the well is used in August when the water table has dropped considerably, problems could arise with the pumping system. Therfore, information about any fluctuation in the water table from year to year or season to season should be submitted. Local residents with nearby wells might be of some help in determining this information.

The pumping test should be conducted in accordance with good well testing procedures. The test should be run for a minimum of three (3) different production rates with the water pumped long enough at each rate to establish ultimate drawdown curves. The last rate should be near the maximum capacity of the well or 70 GPM. Some sprinkler systems require up to 70 GPM so the wells should be test pumped at these flows if possible. The time, pumping rate, and depth to water should be recorded continuously throughout the test. Water level recovery times and rates upon completion

of pumping should also be recorded. The remarks might contain such information as appearance of water, temperature, etc. The length of the pump test will vary greatly depending on the aquifer. A sample of the water should be taken near the end of the test for chemical analysis.

A copy of the well log required by the Water Resources Division of the Department of Natural Resourses and Conservation and a copy of the results of the water quality tests should be attached to Form HYD-2.

B. Springs

Occasionally springs will be developed for water supply. When such a situation arises, the required information will be requested by the Hydraulics Unit on a case by case basis. However, certain information will always be required for the development of a spring. This information includes the elevation of the spring, an approximate flow rate, and the topography surrounding the spring. A water sample for chemical analysis should also be submitted to the Department of Health and Environmental Sciences. Photographs of the area are also quite helpful and should be submitted.

24.04 Waste Water Disposal

Whenever waste water and sewage are created such as in rest areas and weigh stations, some sort of disposal system must be constructed to dispose of them. The type of disposal system used in a particular situation depends primarily on two considerations: (1) the distance (in feet) to the water table from ground elevations and (2) the soil characteristics. A high water table eliminates the possible use of a

drainfield because the Department of Health and Environmental Sciences requires the bottom of the drainfield to be at least 4.5 feet above the maximum ground water table. A highly impervious soil requires such a large drainfield that they become impractical.

The information required for the disposal system design includes a test for the ground water table elevation, percolation tests, and a contour map of the area.

At least one hole should be dug to determine the ground water table elevation. The hole should be excavated until the water table is reached or until it is seven feet deep and water is not encountered. It is felt that if the ground water table is over seven feet deep, it will not affect a drainfield. The ground water table elevation should be measured when the water table is at its highest point during the year. This is normally in the Spring.

Sometimes it is necessary to monitor the ground water elevation for an extended period of time. This is done by placing a shallow well in the ground and periodically recording the water elevation. The well should be placed by digging or boring a minimum of a six inch diameter hole and placing a four inch perforated plastic pipe in it. The hole should then be backfilled with gravel and a cap placed on the top of the plastic pipe. It will be the responsibility of the Hydraulics Unit to request the well and give the approximate placement location. The approximate depth and the frequency with which the water elevation should be recorded will be provided with the request for the well.

Percolation tests determine the acceptability of the site and aid in the design of the subsurface disposal system. The length of time required for making percolation tests will vary in different types of soil. The best method is to make tests holes which have been kept filled overnight with water.

A minimum of four percolation test holes should be made in the drainfield area; more if there is a variation in the soil texture throughout the area. The following procedure is suggested for making percolation tests;

1. Dig or bore the holes 4 to 12 inches in diameter, sides vertical, to a depth of at least three feet. Holes can be bored with a four inch diameter posthole auger.
2. Roughen or scratch the glazed bottom and sides of the holes to provide a natural surface. Remove all loose materials from the hole. Place about two inches of coarse sand or fine gravel in the hole to prevent the bottom from scouring.
3. Fill the hole with clear water to a minimum depth of 12 inches over the gravel. By refilling, if necessary, or by supplying a surplus reservoir of water (automatic siphon), keep water in the hole for at least four hours, and preferably overnight. In sandy soils containing no clay, the above saturation procedure is not necessary and the test can be made after the water from one filling has seeped away.
4. Percolation rate measurements should be made on the day following the saturation process, except in sandy soils.
5. If water remains in the test hole after overnight saturation, adjust the depth to six inches over the gravel. From a fixed reference point, measure the drop in water level over a 30-minute period.
6. If no water remains in the hole after overnight saturation, add clear water to a depth of about six inches over the gravel. From a fixed reference point, measure the height of the water surface at

approximately 30-minute intervals over a four hour period, refilling the hole to a depth of six inches as necessary. The drop which occurs during the final 30-minute period is used to calculate the percolation rate.

7. In sandy soils, or other soils in which the first six inches of water seeps away in less than 30 minutes, after the overnight saturation period, the time interval between measurements can be taken as 10 minutes and the test run over a period of one hour. The drop which occurs in the final 10-minute period is used to calculate the percolation rate.

A contour map of the proposed drainfield area is necessary for the design of the drainfield. A contour interval of at least one foot is required. The unit in charge of selecting the rest area site will request percolation tests for determining the adequacy of the site for a waste disposal system. It is the responsibility of the Hydraulics Unit to request any additional data, such as percolation tests or ground water elevations, for the final waste disposal system design. The Hydraulics Unit will supply a sketch of the rest area which shows the approximate location where the water table should be checked, the number and approximate location of the percolation tests, and the approximate area (including the comfort station) that should be contour mapped.

Any additional information that could be pertinent to the design of a waste disposal system should also be sent to the Hydraulics Unit.

24.05 Water Surface Profile Data

Sometimes it is necessary to determine the elevation of the water surface for a projected flood over a long reach of a stream or irrigation canal instead

of at just one point in the channel. When a stream runs parallel to the highway fill, it is necessary to determine the water surface profile to see how it could affect the fill. When there are several bridges crossing a stream in one vicinity it is necessary to consider all of the bridges together to determine their affect on the stream. These are examples of when it is necessary to determine the water surface profile for a reach of a stream.

It will be the responsibility of the Hydraulics Unit to request the data necessary to calculate the water surface profile. The Hydraulics Unit will supply a map, aerial photograph, or plan sheet which will indicate the reach of the stream for which information is required. The following is a description of the necessary data.

A. Cross Sections

It is necessary to take cross sections that will accurately describe the entire reach. The Hydraulics Unit will indicate on the map, photograph, or plan sheet the locations where cross sections should be taken. In addition, the survey personnel should take additional cross sections when certain conditions exist.

Wherever there is a significant change in area of the channel, the change should be well represented with cross sections. If there is a change in channel shape, such as if the channel changes from a wide, shallow section to a narrow, deep section, the cross sections must represent this. Slope is also represented by the cross sections and additional sections should be taken at all visible changes in slope. A stream that runs from pools to riffles should have sections taken at

the upstream and downstream end of each pool and riffle. The channel material and overbank vegetaion are also represented by the cross sections, so anytime there is a significant change in these parameters, additional sections are required. Cross sections are required above and below the point where a tributary enters the subject stream.

Cross sections should always be taken at right angles to the flow. The sections need not be tied together if their location is accurately shown on a map, aerial photograph, or plan sheet for which a scale can be determined. Each section should be extended far enough to extend above the maximum possible flood.

B. Existing Structures

When a culvert is encountered in the stream, cross sections of the natural channel are required above and below the pipe. The size and type of the culvert and the invert elevations at each end should be recorded. The finished grade elevation above the pipe is also necessary.

When there is an existing bridge, cross sections should be taken in the natural channel above and below the bridge and under the existing bridge. The number, width, and type of piers, the low chord elevations at the abutments, and the finished grade elevations are required.

C. Photographs

Photographs can be used to describe streambed material and overbank vegetation. Well labeled photographs should be taken of every cross section. Pictures should also be taken of the channel above and below each cross section. The photographs should be taken at a time when there is no ice on the stream and no snow to obscure streambed material and vegetation.

24.06 Urban Storm Drainage

The information required to design a storm sewer is extensive and variable. This makes it difficult to give a complete and accurate description of the needed information. The intent here is to give the survey personnel a general idea of what is needed and why it is needed and let them use their judgement in conducting the storm drainage survey.

A. Contributing Area

Determining the area that contributes to the storm sewer run-off is the most difficult part of the storm sewer survey. Most storm sewers pick up water that runs onto the highway from side streets. A detailed description of side drainages should be given so drainage areas and run-off coefficients can be determined. The description should include such information as drainage limits, direction of flow on each street, street widths, type of surfacing, land use (residential, commercial, etc.), location at which it intercepts the highway, and location and size of any large paved areas such as parking lots. If there is an existing storm sewer in place in any of the contributing areas, the location of all inlets, manholes, and the size of pipe should be given. Most of this information can most easily be given on a map of the area that is drawn to scale and is large enough to show all necessary details. Any other information that could be pertinent to the design of the storm sewer system should also be included.

B. Outfalls

It is always necessary to discharge the storm sewer into a natural drainage at some point or points along the system. It is the responsibility of the survey personnel to search out all possible outfall lines and provide

a survey of each line. Some storm sewers will not have an obvious outfall line and a very detailed search will be required. If no outfall line can be found, the Hydraulics Unit should be so informed. The outfall survey should include a traverse tied to the centerline survey, property ties, all pertinent topography, and a profile.

C. Settling Basin

Anytime a storm sewer is discharged into a perennial stream that contains fish life or is used extensively for drinking water, a settling basin is required near the stream. The purpose of the settling basin is to settle out silt, sand, and gravel. It can also be used, on occasion, as a seepage pit to allow some of the storm water to seep out naturally.

The settling pond should be located on the outfall line after all of the water has been collected. The shape of the basin can be varied to fit the area available. A minimum of one acre of land is required and it must be on or immediately adjacent to the outfall line. A contour map should be made of the prospective settling basin with a contour interval of one foot. This map should be submitted to the Hydraulics Unit with the other storm sewer survey data.

D. Utilities

All buried utilities that could affect the installation of the storm sewer must be accurately located. The size, depth, and location of each utility must be recorded. The depth given should be referenced to some datum. The invert elevations of all manholes and connections on gravity systems such as sanitary sewers and storm sewers should be given when possible. The utility companies and the city will have to be contacted to

get most of this information. If for some reason they cannot provide the needed information, some field work may be necessary.

24.07 Small Earth Fill Dams

It is sometimes possible to use a highway fill as a small dam and back up water either for flood routing purposes or for use as a stock pond. This situation will usually require a crossing with a small drainage area (ten square miles or less) and a high fill. In order to safely design such a crossing, some special information is required in addition to a completely filled out waterway crossing sheet (Form HYD-1). It will be the responsibility of the Hydraulics Unit to request the additional information when it is felt the fill could possibly be used in this manner.

A discussion of damage that could result if the fill washed out should be given. The location and description of all buildings, crops, ditches, etc. that are downstream from the highway and could be damaged should be submitted.

It is necessary to determine the storage capacity of the reservoir that will build up behind the fill. In order to do this, a contour map of the area upstream is required. A contour interval of five feet is normally sufficient. The contours should go as high as the top of the fill.

The location and elevation of anything on the upstream side of the fill that could be flooded and damaged should be recorded. Some description of the land and vegetation that could be flooded should also be provided.

It will also be the responsibility of the Hydraulics Unit to request the Materials Bureau to supply a soils survey and their recommendations for construction of the fill.

24.08 Roadside Erosion

Erosion in roadside ditches, median ditches, on cut and fill slopes, etc., is a problem that should be handled during the original design. However, because of the lack of information and the tremendous amount of work involved in checking every situation on every project, provisions for erosion control are rarely designed for the original design. The best way to recognize potential erosion situations is by reviewing similar situations in the immediate vicinity.

It shall be the responsibility of the survey personnel to recognize, note and comment on all potential erosion locations at the time the location survey is made. Note should be taken of any erosion in existing roadside ditches, on cut and fill slopes, on hill sides, and in nearby gullies. If these locations show signs of erosion then the potential for erosion of the newly exposed slopes of the new highway is great. If a particular erosion control method or material has worked well in the past in the vicinity, recommendations concerning that particular method or material should be made.

FORM HYD 1 Example No 1 Intermediate Watershed

MONTANA DEPT OF HIGHWAYS

Survey Data for Design of Waterways

Project Big Timber-Roadpoint No BR-2717)
Stream Name Upper Deer Creek Sta 343+86.6
County Sweetgrass
Surveyed By R.W. Sallaman Date 6 3 76

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION

GENERAL INSTRUCTIONS

1 Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples
2 Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing
3 Comments of local residents will aid in filling out much of this information The division lab may be of some help when filling out Section 3
4 The ditch rider, farmer, or ditch company should be contacted when filling out Section 4 Attach any right-of-way agreements if they have been made
5 Submit all survey notes with this sheet
6 Submit photographs of all channel and overbank areas and all existing structures Be sure they are well labeled Indicate the location and orientation of all photographs with an arrow(▷) in Section 8

SECTION 1 WATERSHED DATA

Estimated Drainage Area 61 Acres or Sq Miles
Area not contributing to runoff none
Comment on land use or cover 13 Mountainous (60% Forest Cover), 12 Range and 4 Irrigation
Floating Debris None ☐, Light ☐, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris
Ice Light ☐, Moderate ☐, Severe ☐.
Unusual Characteristics none
Elev of water on date of survey 3964.0
Elev of low water 3963.5, normally dry ☐
Elev of high water 3972.0, date occured June 96?
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☐, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property Yes If so what elev will water be allowed to reach 3973.0
Should crossing be designed for fish passage Yes
*The elevations are measured at the upstream edge of the existing bridge

SECTION 2 EXISTING STRUCTURE

A Culvert Size , Type
Condition , Length
B Bridge Type Steel and Concrete
No of spans , Length of each span 38'
Clearance 8.5
Condition Bridge fair, Abutments-poor
C Approx distance above or below site on centerline
High water mark elev 3967.0
Historical adequacy Washed out in 1967 See Comment below
Comments

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? Yes, is channel stable ☐ degrading ☐, aggrading ☐, unknown ☐ Is riprap or bank protection necessary? Yes
Are the following material available locally
Riprap Yes, Type No 8, Filter Material No 1 Yes, No 2 Yes
Is water or soil alkaline No, acidic No, are sulphates present No
Comments

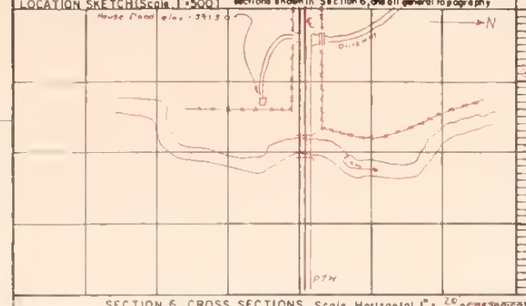
SECTION 4 IRRIGATION DATA

Name of ditch
Owner
Address of ditch company
Ditch capacity , Slope , Water Depth , Bottom width , Side Slopes , Total Depth
Does ditch carry flood water also? Flow line elevations of existing structure, inlet , outlet

COMMENTS Present structure has been adequate to handle the flow during normal runoff. A 3.9" rainfall in 48 hours, in June 1967, caused a flash flood that undermined the abutments of this bridge on U.S. Highway 10. Debris blocking the inlet end of this structure was a partial cause of the failure. In the event of a flood such as in June, 1967 the present highway bridge could wash out again due to the heavy debris and downed timber in the stream bed.

SECTION 5 LOCATION SKETCH (Scale 1"=500')

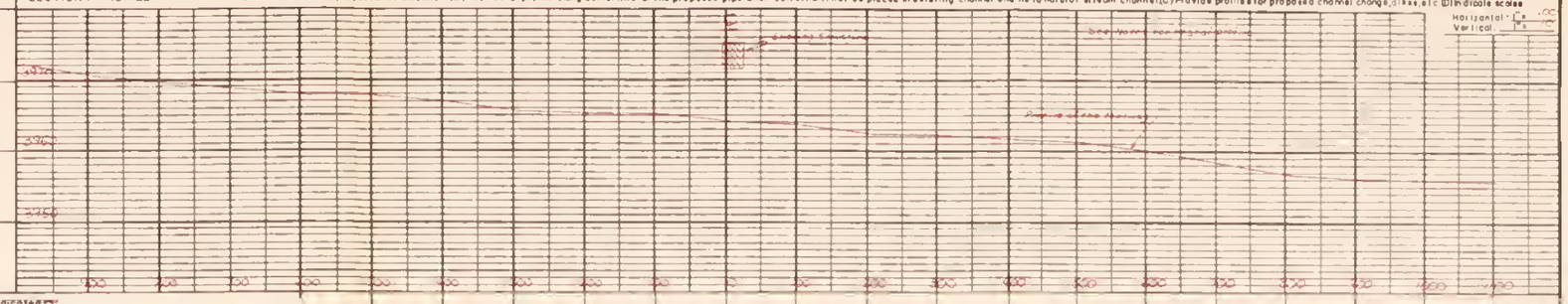
Instructions Show ℄ of survey, north arrow, general course of stream, existing structures, location of all channel cross-sections shown in Section 6, and all general topography



SECTION 7 PROFILE

Instructions (A) Provide profiles of both the water surface and flowline of the existing channel for a minimum distance of 1500 ft up and downstream from the centerline Extend this profile when necessary to incorporate ties to natural or manmade features that will influence the proposed construction (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and tie to natural stream channel (C) Provide profiles for proposed channel changes, dikes, etc (D) Indicate scales

Horizontal 1" = 100'
Vertical 1" = 10'


3976
3966
3956
Proposed Roadway
Proposed Channel
Existing Channel
Bottom and Boundary Composition
100 100 100

FORM HYD 1 Example No 2 Large Watershed

MONTANA DEPT OF HIGHWAYS

Survey Data for Design of Waterways

Project St Regis E&W No F-90-1(3)27
Stream Name Clark Fork River Sta 628+00
County Mineral
Surveyed By JDH JDC Date 7-2-68

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION

GENERAL INSTRUCTIONS

1 Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples
2 Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing
3 Comments of local residents will aid in filling out much of this information The division foreman may be of some help when filling out Section 3
4 The ditch rider, farmer, or ditch company should be contacted when filling out Section 4 Attach any right-of-way agreements if they have been made
5 Submit all survey notes with this sheet
6 Submit photographs of all channel and overbank areas and all existing structures Be sure they are well labeled Indicate the location and orientation of all photographs with an arrow (▷) in Section 8

SECTION 1 WATERSHED DATA

Estimated Drainage Area 10,000 Acres or Sq Miles
Area not contributing to runoff Negligible
Comment on land use or cover Mountainous

Floating Debris None ☐, Light ☐, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris
Ice Light ☐, Moderate ☐, Severe ☐
Unusual Characteristics None

Elev of water on date of survey 2607.5
Elev of low water 2508.7, normally dry ☐
Elev of high water 2620.1, date occured 5-9 1948
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☐, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property No If so what elev will water be allowed to reach —
Should crossing be designed for fish passage Yes

SECTION 2 EXISTING STRUCTURE

A Culvert Size —, Type —
Condition —, Length —
B Bridge Type Concrete and Truss Spans
No of spans 7, Length of each span 20.9 2.5, 57.7 5, 2 2 5.1 5, —
Clearance 35.2
Condition Good
C Approx distance above or below elev 350 Below Elev
Highwater mark elev 2610.9
Historical adequacy Very Good

Comments —

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? No, is channel stable ☐, degrading ☐, aggrading ☐, unknown ☐ Is riprap or bank protection necessary? No
Are the following material available locally
Riprap Yes, Type B, Filter Material No 1 Yes, No 2 Yes
Is water or soil alkaline No, acidic No, are sulphates present No
Comments —

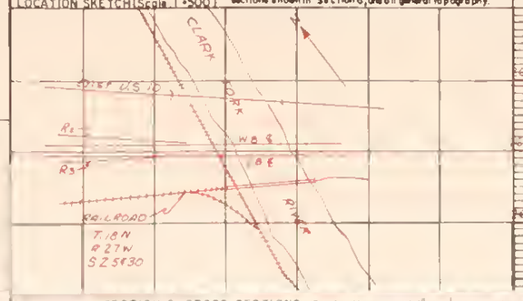
SECTION 4 IRRIGATION DATA

Name of ditch —
Owner —
Address of ditch company —
Ditch capacity —, Slope —, Water Depth —, Bottom width —, Side Slopes —, Total Depth —
Does ditch carry flood water also? — Flow line elevations of existing structure, inlet —, outlet —

COMMENTS It was felt that because of the uniformity of the channel one cross section adequately described this crossing Neither the PTN or the railroad present any constriction

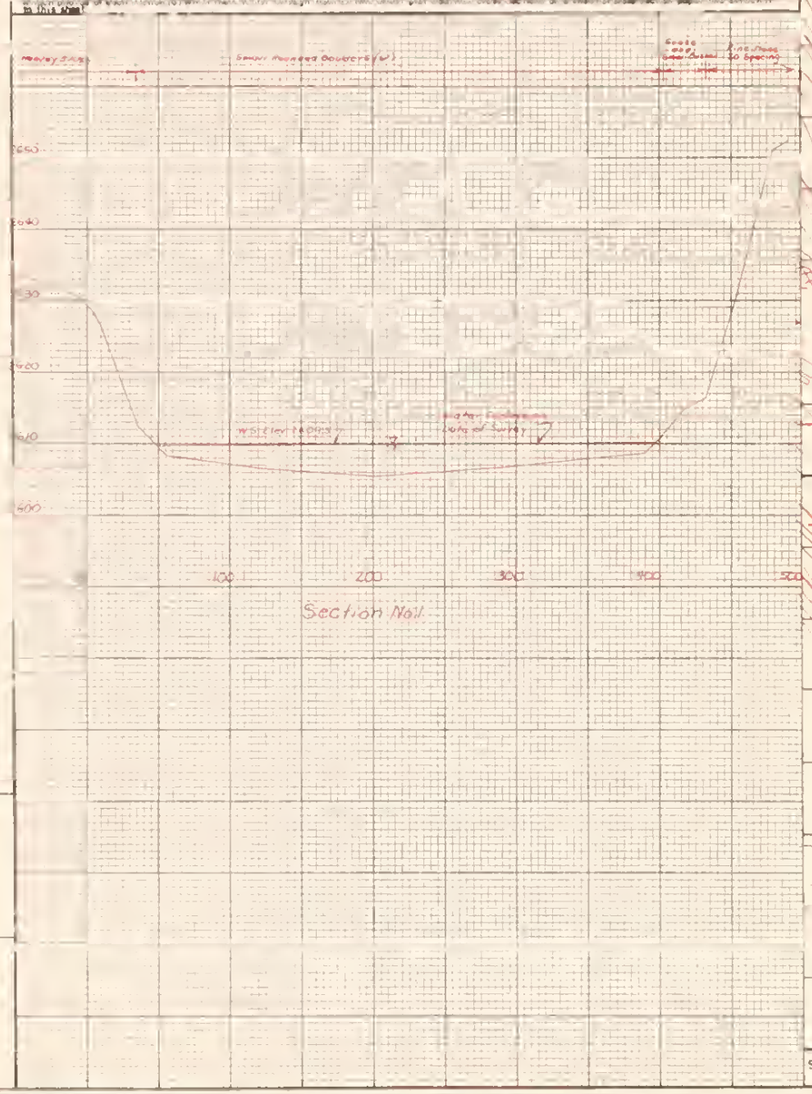
SECTION 5 LOCATION SKETCH Scale 1"=500'

Instructions Show ℄ of survey, north arrow, general course of stream, existing structures, location of pit, channel cross-sections shown in Section 6, and all general topography.



SECTION 6 CROSS SECTIONS Scale Horizontal 1"=100' or as indicated ☐
Vertical 1"=10' or as indicated ☐

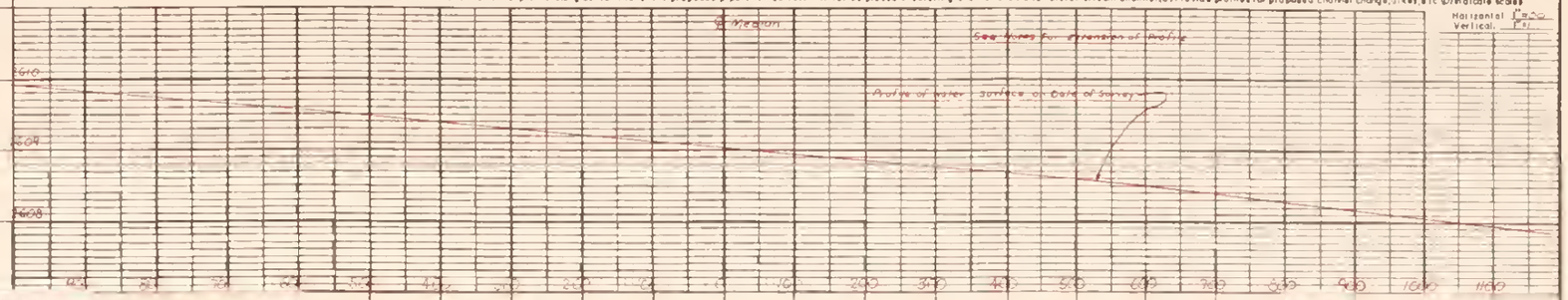
Instructions Note cross sections should embody the following general characteristics (1) Normal to channel (2) Section extended to extend well above the maximum possible flood, (3) Vegetation described and accurately located, (4) Elevation differences of 6" or greater defined (5) Use scale of 1"=10' vertical and horizontal unless there is an extensive flood plain In this case, a smaller horizontal scale may be used so as to define the flood plain and low water channel The low water portion should also be plotted again using a larger scale
(A) Provide typical section downstream from all proposed structures (B) Provide cross-section at approximate construction limits upstream and downstream from all proposed crossings (C) Provide section under existing bridges to include substructure details, spill slopes, channel, and high water marks (D) Provide typical section of any irrigation ditches, etc that will be effected by the construction (E) Indicate location of each section in Section 5 and 8 (F) [illegible] to this sheet



SECTION 7 PROFILE

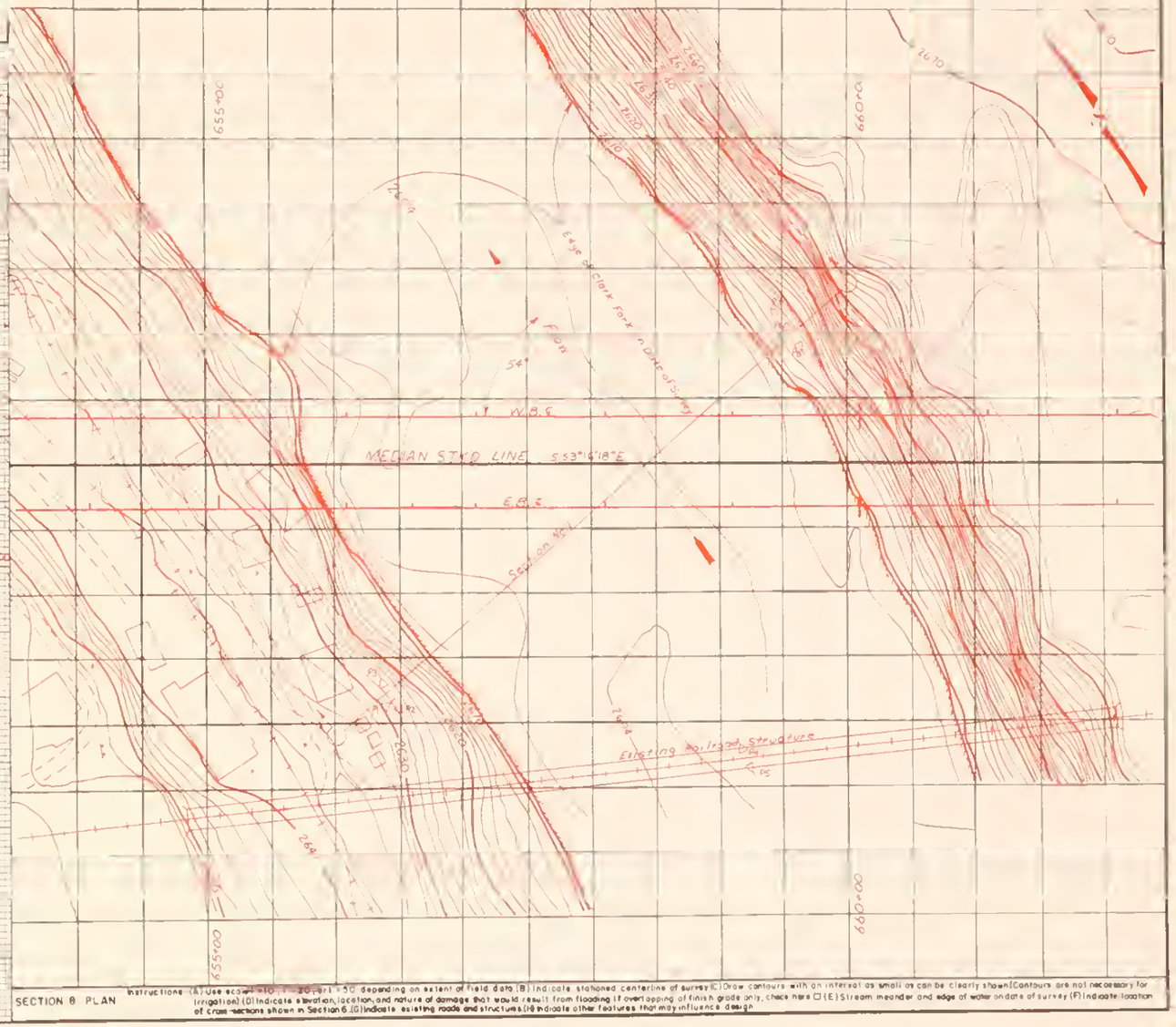
Instructions (A) Provide profiles of both the water surface and flowline of the existing channel for a minimum distance of 1500 ft up and downstream from the centerline Extend this profile when necessary to incorporate ties to natural or man-made features that will influence the proposed construction (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and tie to natural stream channel (C) Provide profiles for proposed channel changes, dikes, etc (D) Indicate scales

Horizontal 1"=200'
Vertical 1"=20'



SECTION 8 PLAN

Instructions (A) Use scale of 1"=20', 1"=30', or 1"=50' depending on extent of field data (B) Indicate stationed centerline of survey (C) Draw contours with an interval as small as can be clearly shown (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that would result from flooding (if overlapping of finish grade only, check here ☐ (E) Stream meander and edge of water on date of survey (F) Indicate location of cross-sections shown in Section 6 (G) Indicate existing roads and structures (H) Indicate other features that may influence design



FORM HYD 1 Example No. 3 Large Watershed

MONTANA DEPT OF HIGHWAYS

Survey Data for Design of Waterways

Project Bridge-Ease No S 460(3)
Stream Name Little Beaver Ease Sta 7+50
County Hoover Ease
Surveyed By C.W. Taylor Date 6-29-70

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION

GENERAL INSTRUCTIONS

1 Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples
2 Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing
3 Comments of local residents will aid in filling out much of this information The division foreman may be of some help when filling out Section 3
4 The ditch rider, farmer, or ditch company should be contacted when filling out Section 4 Attach any right-of-way agreements if they have been made
5 Submit all survey notes with this sheet
6 Submit photographs of all channel and overbank areas, and all existing structures Be sure they are well labeled Indicate the location and orientation of all photographs with an arrow(▷) in Section 8

SECTION 1 WATERSHED DATA

Estimated Drainage Area 1.50 Acres or Sq Miles
Area not contributing to runoff None
Comment on land use or cover 99% Range land

Floating Debris None ☐, Light ☐, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris
Ice Light ☐, Moderate ☐, Severe ☐
Unusual Characteristics None

Elev of water on date of survey 3250.9
Elev of low water 3249.8, normally dry ☐
Elev of high water 3256.9, date occured ?
Cause Back-water from ice ☐, Back-water from Construction ☐, Cloudburst ☐, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property Yes If so what elev will water be allowed to reach 3261.5
Should crossing be designed for fish passage No

SECTION 2 EXISTING STRUCTURE

A Culvert Size , Type
Condition , Length
B Bridge Type Steel Truss
No of spans 1 , Length of each span 107
Clearance 22.5'
Condition Poor
C Approx distance above or below site 100 Downstream
High water mark elev 3257.9
Historical adequacy This crossing has always been adequate
Comments

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? No , is channel stable ☐, degrading ☐, aggrading ☐, unknown ☐ Is riprap or bank protection necessary? Yes
Are the following material available locally
Riprap Yes , Type A , Filter Material No 1 No , No 2 No
Is water or soil alkaline Yes , acidic No , ore sulphates present No
Comments

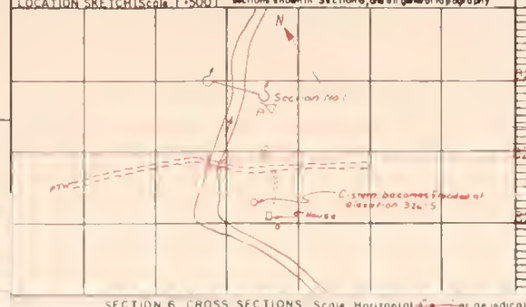
SECTION 4 IRRIGATION DATA

Name of ditch
Owner
Address of ditch company
Ditch capacity , Slope , Water Depth , Bottom width , Side Slopes , Total Depth
Does ditch carry flood water also? Flow line elevations of existing structure, inlet outlet

COMMENTS This water district is privately in August, 1967

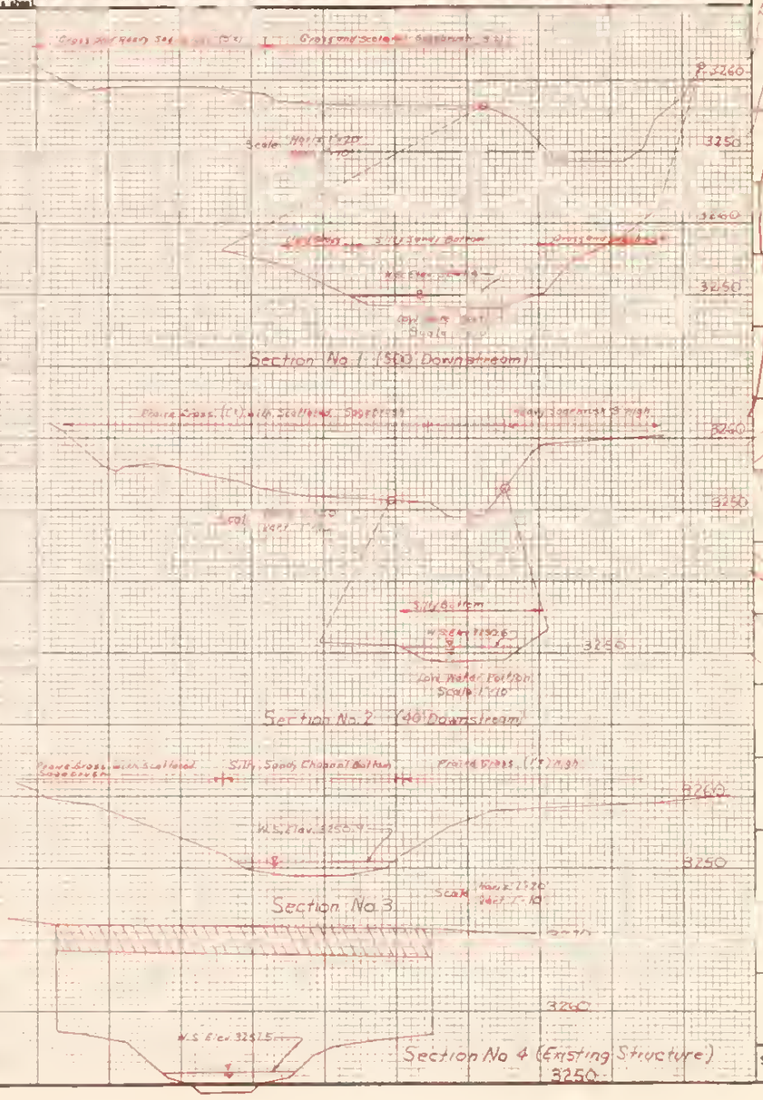
SECTION 5 LOCATION SKETCH (Scale 1"=500')

Instructions Show ℄ of survey, north arrow, general course of stream, existing structures, location of all channel cross-sections shown in Section 6, and all general topography



SECTION 6 CROSS SECTIONS Scale Horizontal 1"=20' or as indicated ☐
Vertical 1"=10' or as indicated ☐

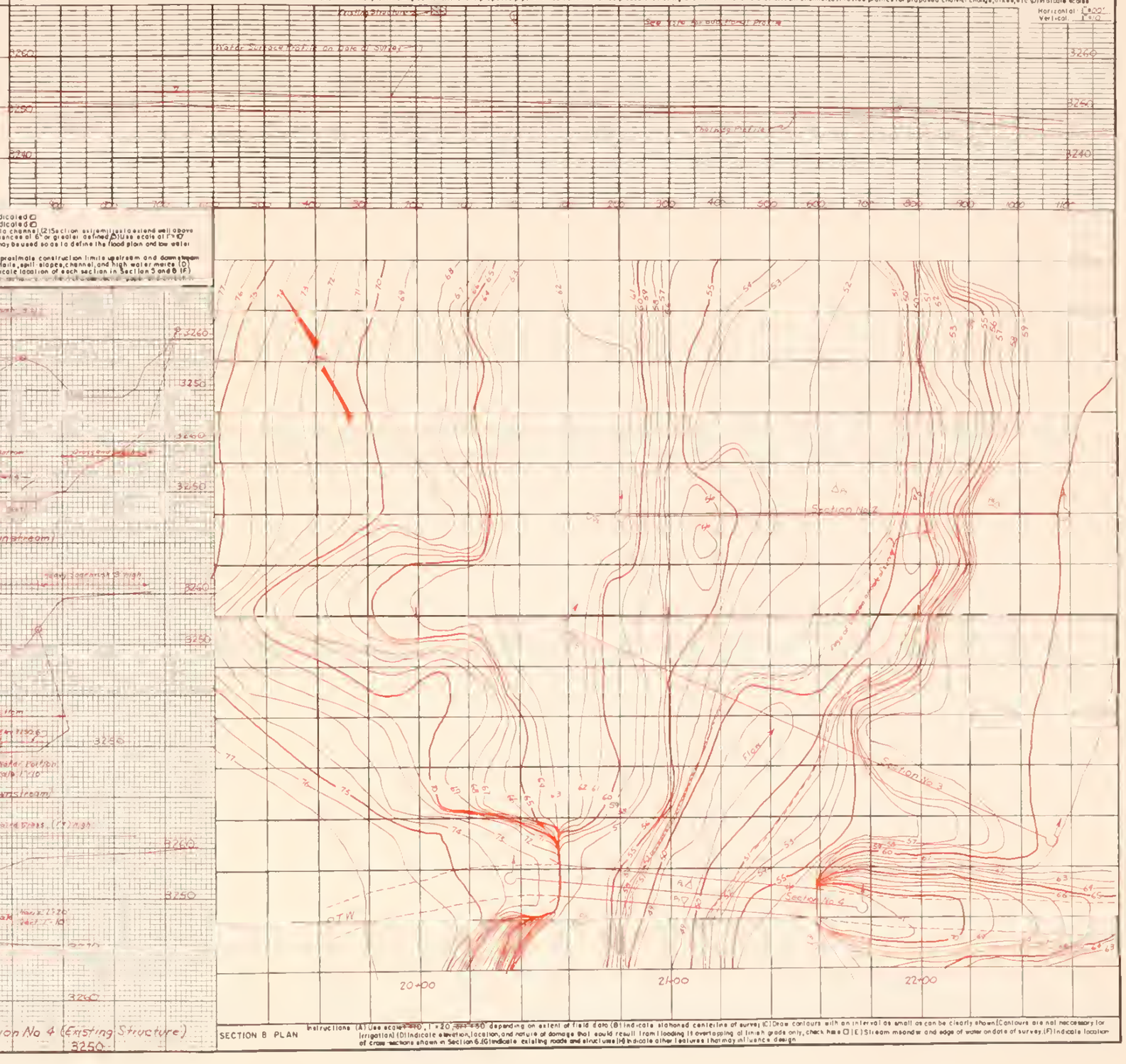
Instructions Note, cross-sections should embody the following general characteristics, (1) Normal to channel, (2) Section extends well above the maximum possible flood, (3) Vegetation described and accurately located, (4) Elevation differences of 6" or greater defined, (5) Use scale of 1"=10' vertical and horizontal unless there is an extensive flood plain In this case, a smaller horizontal scale may be used so as to define the flood plain and low water channel The low water portion should also be plotted again using a larger scale
(A) Provide typical section downstream from all proposed structures (B) Provide cross-section at approximate construction limits upstream and downstream from all proposed crossings (C) Provide section under existing bridges to include superstructure details, spill slopes, channel, and high water marks (D) Provide typical section of any irrigation ditches etc that will be affected by the construction (E) Indicate location of each section in Section 5 and 8 (F) Indicate location of each section on the plan sheet in this sheet


Ground Surface Scale Horiz 1"=20' Vert 1"=10'
Ground Surface Scale Horiz 1"=20' Vert 1"=10'
Scale Horiz 1"=20' Vert 1"=10'
Section No 1 (500' Downstream)
Section No 2 (40' Downstream)
Section No 3
Section No 4 (Existing Structure)
Silty, Sandy Channel Bottom
W.S. Elev. 3257.5

SECTION 7 PROFILE

Instructions (A) Provide profiles of both the water surface and flowline of the existing channel for a minimum distance of 1500 ft up and downstream from the centerline Extend the profile when necessary to incorporate ties to natural or manmade features that will influence the proposed construction (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and tie to natural stream channel (C) Provide profiles for proposed channel change, dikes, etc (D) Indicate scales

Horizontal 1"=200'
Vertical 1"=10'



SECTION 8 PLAN

Instructions (A) Use scale 1"=10', 1"=20', 1"=30', 1"=50' depending on extent of field data (B) Indicate stationed centerline of survey (C) Draw contours with an interval as small as can be clearly shown (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that could result from flooding (It overlapping of lines grade only, check here ☐) (E) Stream meander and edge of water on date of survey (F) Indicate location of cross-sections shown in Section 6 (G) Indicate existing roads and structures (H) Indicate other features that may influence design

FORM HYD 1 Example No 4 Small Watershed

MONTANA DEPT OF HIGHWAYS

Survey Data for Design of Waterways

Project Turner South No S 291(6)
Stream Name Bell Coulee Sta 119+50
County Blaine
Surveyed By R. W. Hirschman Date 4-9-73

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION

GENERAL INSTRUCTIONS

1 Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples
2 Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing
3 Comments of local residents will aid in filling out much of this information The division HQ may be of some help when filling out Section 3
4 The ditch rider, farmer, or ditch company should be contacted when filling out Section 4 Attach any right-of-way agreements if they have been made
5 Submit all survey notes with this sheet
6 Submit photographs of all channel and overbank areas and all existing structures Be sure they are well labeled Indicate the location and orientation of all photographs with an arrow (▷) in Section 8

SECTION 1 WATERSHED DATA

Estimated Drainage Area 1500 Acres or ~~Sq Miles~~
Area not contributing to runoff none
Comment on land use or cover 90% Dry Land wheat

Flooding Debris None ☐, Light ☐, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris
Ice Light ☐, Moderate ☐, Severe ☐,
Unusual Characteristics

Elev of water on date of survey Dry
Elev of low water , normally dry ☐
Elev of high water ?, date occured
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☐, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property No If so what elev will water be allowed to reach
Should crossing be designed for fish passage No

SECTION 2 EXISTING STRUCTURE None

A Culvert Size , Type
Condition , Length
B Bridge Type
No of spans , Length of each span
,
Clearance
Condition
C Approx distance above or below site
Highwater mark elev
Historical adequacy

Comments

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour Yes, is channel stable ☐, degrading ☐, aggrading ☐, unknown ☐ Is riprap or bank protection necessary? Yes
Are the following material available locally
Riprap Yes, Type B & A, Filter Material No 1 Yes, No 2 Yes
Is water or soil alkaline No, acidic No, are sulpholes present No
Comments

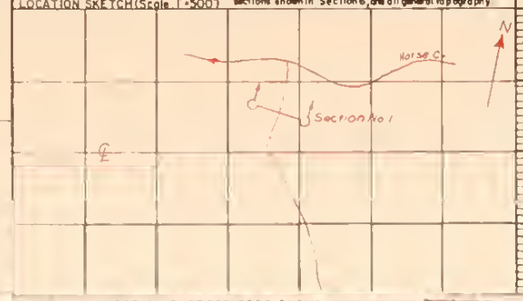
SECTION 4 IRRIGATION DATA

Name of ditch
Owner
Address of ditch company
Ditch capacity Slope , Water Depth , Bottom width , Side Slopes , Total Depth
Does ditch carry flood water also? Flow line elevations of existing structure, inlet outlet

COMMENTS

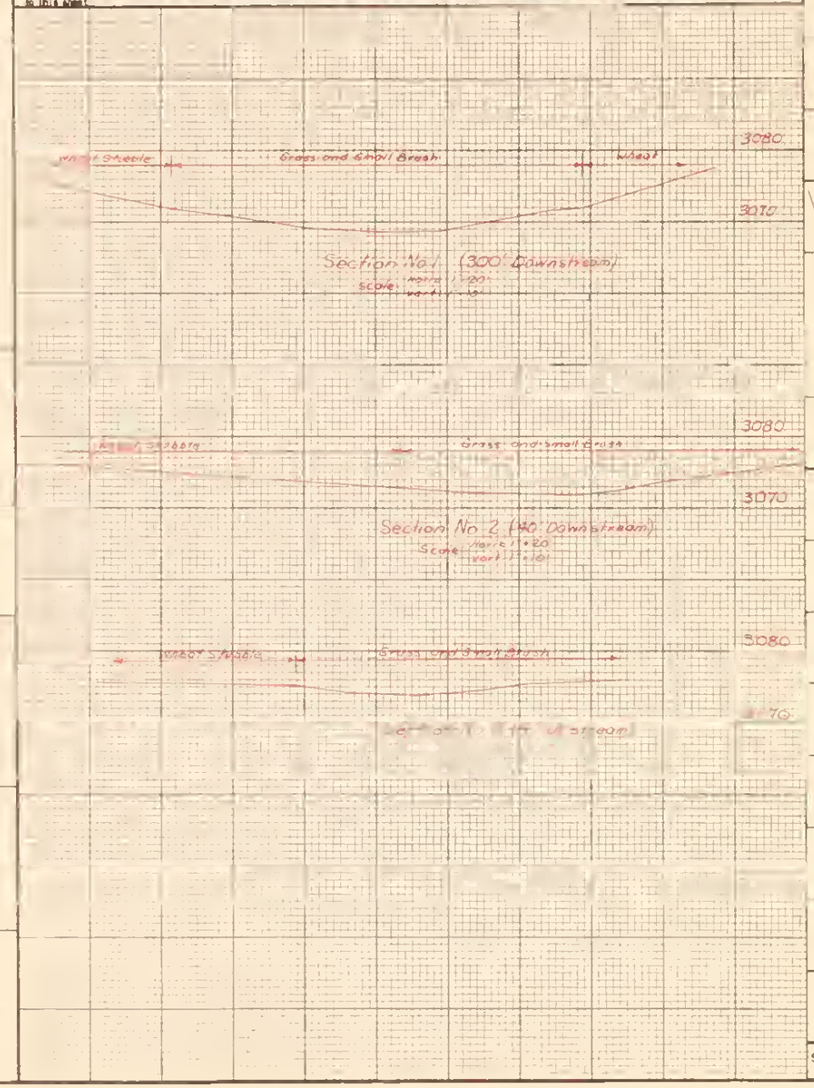
SECTION 5 LOCATION SKETCH (Scale 1"=500')

Instructions Show ℄ of survey, north arrow, general course of stream, existing structures, location of pi channel cross sections shown in Section 6, and all general topography



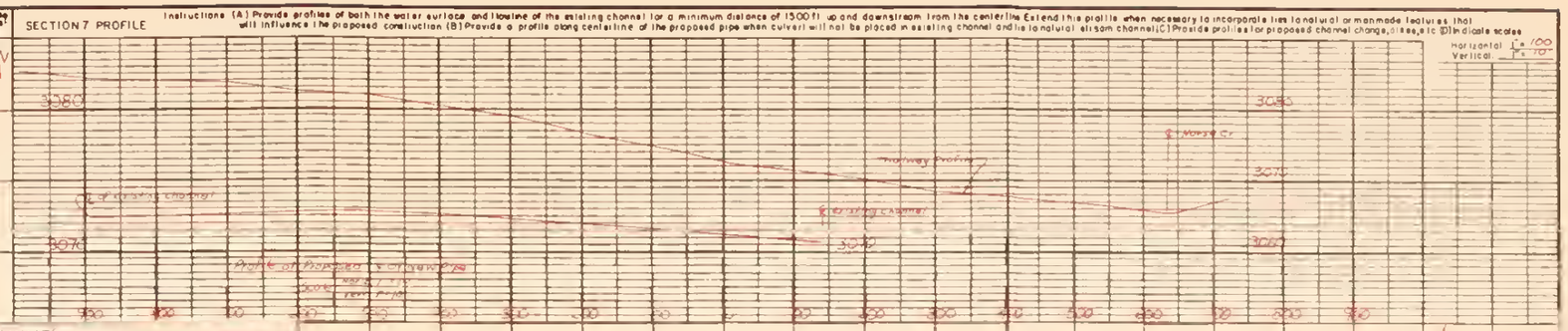
SECTION 6 CROSS SECTIONS Scale Horizontal 1"= 10' or as indicated ☐
Vertical 1"= 10' or as indicated ☐

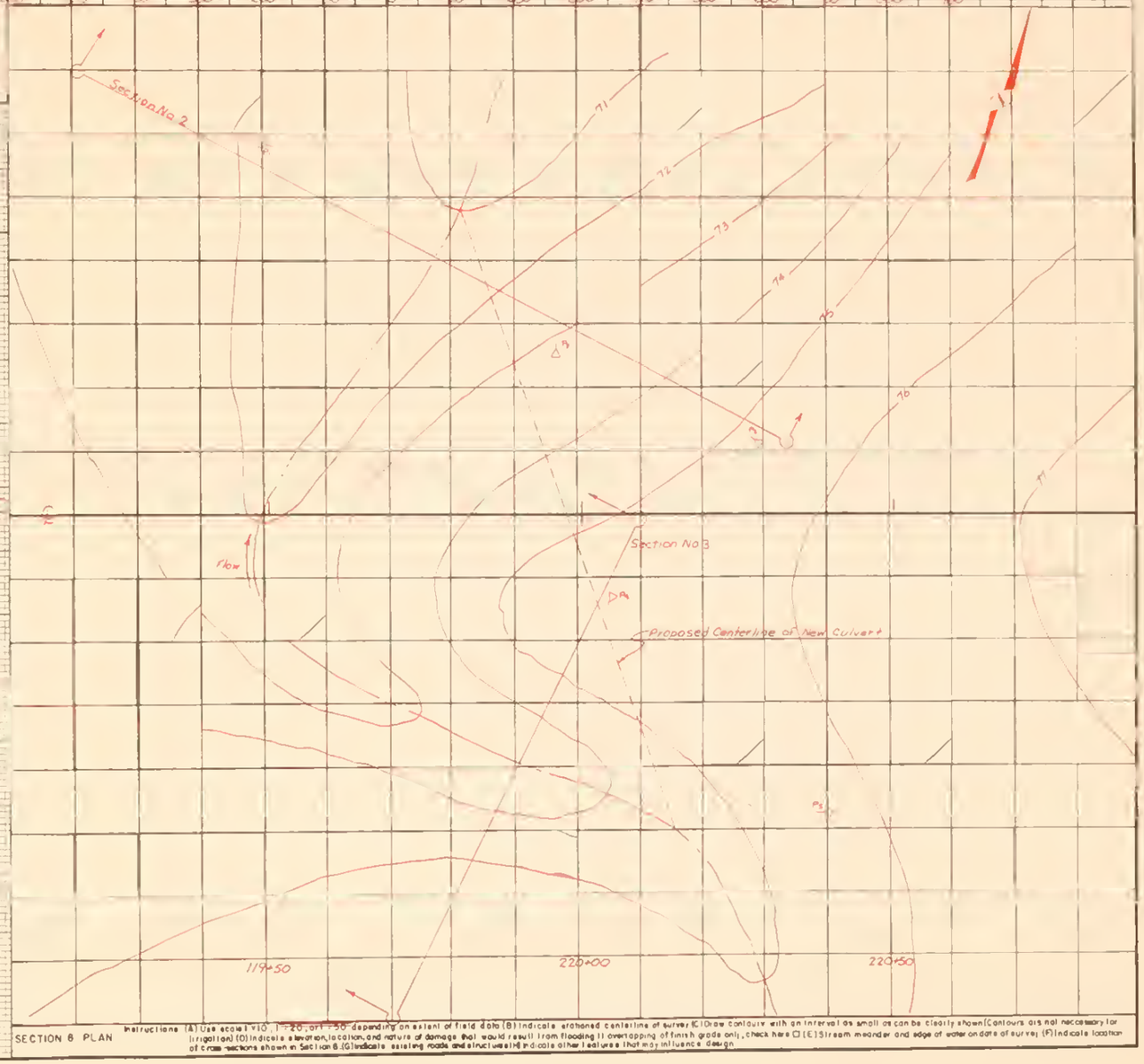
Instructions Make cross-sections should embody the following general characteristics, (1) Normal to channel, (2) Section as far as necessary to extend well above the maximum possible flood, (3) Vegetation described and accurately located, (4) Elevation differences of 6" or greater defined, (5) Use scale of 1" = 10' vertical and horizontal unless there is an extensive flood plain In this case, a smaller horizontal scale may be used so as to define the flood plain and low water channel The low water portion should also be plotted again using a larger scale
(A) Provide typical section downstream from all proposed structures (B) Provide cross section of approximate construction limits upstream and downstream from all proposed crossings (C) Provide section under existing bridges to include substructure details, spill-slopes, channel, and high water marks (D) Provide typical section of any irrigation ditches, etc that will be affected by the construction (E) Indicate location of each section in Section 5 and 8 (F) Number each cross-section and identify it on the survey drawing in Section 8 to this sheet



SECTION 7 PROFILE

Instructions (A) Provide profiles of both the water surface and flowline of the existing channel for a minimum distance of 1500 ft up and downstream from the centerline Extend this profile when necessary to incorporate lines of natural or man-made features that will influence the proposed construction (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and/or a natural ephemeral channel (C) Provide profiles for proposed channel changes, dikes, etc (D) Indicate scales Horizontal 1"= 100' Vertical 1"= 10'





SECTION 8 PLAN

Instructions (A) Use scale 1"=10', 1"=20', or 1"=50' depending on extent of field data (B) Indicate enhanced centerline of survey (C) Draw contours with an interval as small as can be clearly shown (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that would result from flooding (if overtopping of finish grade only, check here ☐ (E) Stream meander and edge of water on date of survey (F) Indicate location of cross-sections shown in Section 6 (G) Indicate existing roads and structures (H) Indicate other features that may influence design

FORM HYD 1 Example No 5 Small Watershed

MONTANA DEPT OF HIGHWAYS

Survey Data for Design of Waterways

Project [illegible] No [illegible]
Stream Name [illegible] Sta [illegible]
County [illegible]
Surveyed By [illegible] Date [illegible]

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION

GENERAL INSTRUCTIONS

1 Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples
2 Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing
3 Comments of local residents will aid in filling out much of this information The division lab may be of some help when filling out Section 3
4 The ditch rider, former, of ditch company should be contacted when filling out Section 4 Attach any right of way agreements if they have been made
5 Submit all survey notes with this sheet
6 Submit photographs of all channel and overbank areas, and all existing structures Be sure they are well labeled Indicate the location and orientation of all photographs with an arrow(▷) in Section 8

SECTION 1 WATERSHED DATA

Estimated Drainage Area [illegible] Acres or Sq Miles
Area not contributing to runoff [illegible]
Comment on land use or cover [illegible]

Floating Debris None ☐, Light ☐, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris [illegible]
Ice Light ☐, Moderate ☐, Severe ☐
Unusual Characteristics [illegible]
Elev of water on date of survey [illegible]
Elev of low water [illegible], normally dry ☐
Elev of high water [illegible], date occured [illegible]
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☐, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property [illegible] If so what elev will water be allowed to reach [illegible]
Should crossing be designed for fish passage [illegible]

SECTION 2 EXISTING STRUCTURE

A Culvert Size [illegible], Type [illegible]
Condition [illegible], Length [illegible]
B Bridge Type [illegible]
No of spans [illegible] Length of each span
Clearance [illegible]
Condition [illegible]
C Approx distance above or below site [illegible]
Highwater mark elev [illegible]
Historical adequacy [illegible]
Comments [illegible]

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? [illegible], is channel stable ☐, degrading ☐, agrading ☐, unknown ☐ Is riprap or bank protection necessary? [illegible]
Are the following material available locally
Riprap [illegible], Type [illegible], Filter Material No 1 [illegible], No 2 [illegible]
Is water or soil alkaline [illegible], acidic [illegible], are sulphates present [illegible]
Comments [illegible]

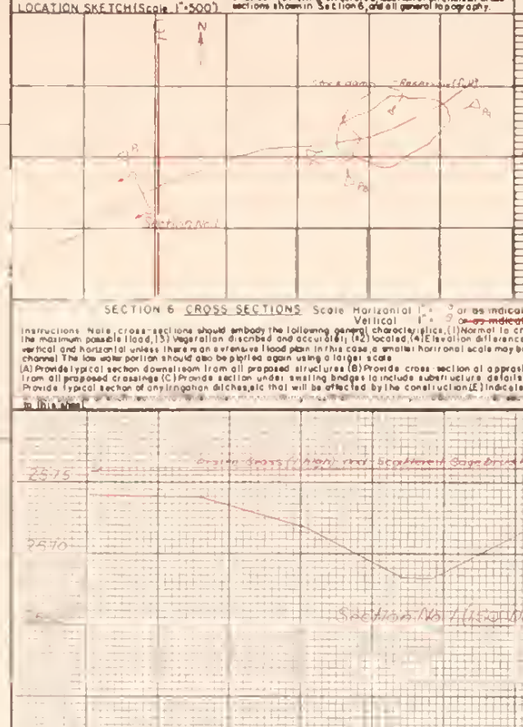
SECTION 4 IRRIGATION DATA

Name of ditch [illegible]
Owner [illegible]
Address of ditch company [illegible]
Ditch capacity [illegible] Slope [illegible], Water Depth [illegible], Bottom width [illegible], Side Slopes [illegible], Total Depth [illegible]
Does ditch carry flood water also? [illegible] Flow line elevations of existing structure, inlet [illegible] outlet [illegible]

COMMENTS [illegible]

SECTION 5 LOCATION SKETCH (Scale 1"=500')

Instructions Show ℄ of survey, north arrow, general course of stream, existing structures, location of all channel cross sections shown in Section 6, and all general topography.


N
Section No 1
Section No 2
Section No 3
Brush
Brush
Brush

FORM HYD 1 Exomple No. 6 Complex Irrigotion

MONTANA DEPT OF HIGHWAYS

Survey Data for Design of Waterways

Project Fairfield EFN No F-65(7)
Stream Name Greenfield Ditch Sta 181+65
County Teton
Surveyed By C.Au. Date 2-22-72

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION

GENERAL INSTRUCTIONS

1 Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples
2 Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing
3 Comments of local residents will aid in filling out much of this information The division rdo may be of some help when filling out Section 3
4 The ditch rider, farmer, or ditch company should be contacted when filling out Section 4 Attach any right-of-way agreements if they have been made
5 Submit all survey notes with this sheet
6 Submit photographs of all channel and overbank areas and all existing structures Be sure they are well labeled Indicate the location and orientation of all photographs with an arrow(▷) in Section 8

SECTION 1 WATERSHED DATA

Estimated Drainage Area ____ Acres or Sq Miles
Area not contributing to runoff ____
Comment on land use or cover ____

Floating Debris None ☐, Light ☐, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris ____
Ice Light ☐, Moderate ☐, Severe ☐.
Unusual Characteristics ____

Elev of water on date of survey ____
Elev of low water ____, normally dry ☐
Elev of high water ____, date occured ____
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☐, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property ____ If so what elev will water be allowed to reach ____
Should crossing be designed for fish passage ____

SECTION 2 EXISTING STRUCTURE

A Culvert Size ____, Type ____
Condition ____, Length ____
B Bridge Type Flat Slab Concrete
No of spans 1, Length of each span 26.0', ____, ____
Clearance (From low beam) 4.5
Condition Fair (Some concrete is scaling)
C Approx distance above or below site Same Site
Highwater mark elev ____
Historical adequacy Adequate
Comments ____

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? No, is channel stable ☐, degrading ☐, aggrading ☐, unknown ☐ Is riprap or bank protection necessary? No
Are the following material available locally
Riprap Yes, Type Rock, Filter Material No 1 Yes, No 2 Yes
Is water or soil alkaline No, acidic No, are sulphates present No
Comments ____

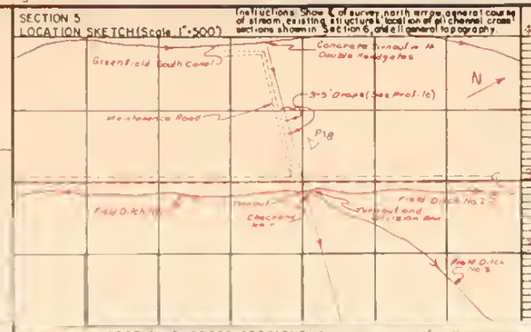
SECTION 4 IRRIGATION DATA

Name of ditch Greenfield Ditch
Owner Greenfield Irrigation Co
Address of ditch company Fairfield Mont
Ditch capacity 40 cfs Slope .0008, Water Depth 3.5, Bottom width 10.0', Side Slopes 2:1, Total Depth ____
Does ditch carry flood water also? No Flow line elevations of existing structure, inlet ____ outlet ____

COMMENTS Greenfield Irrigation Co said they felt a culvert was unacceptable for this crossing They also said that require 2' minimum freeboard on all bridges crossing their canals.

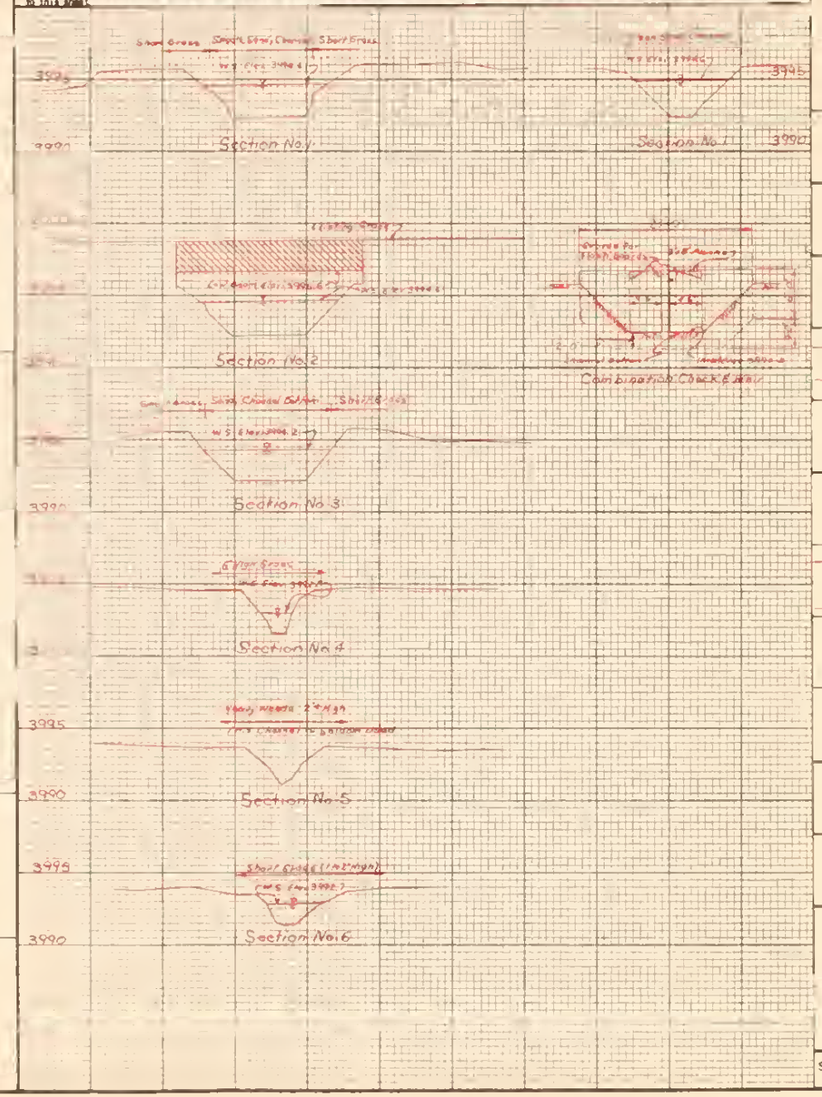
SECTION 5 LOCATION SKETCH (Scale 1"=500')

Instructions Show N of survey, north arrow, general course of stream, existing structures, location of pt channel cross sections shown in Section 6, and all general topography.



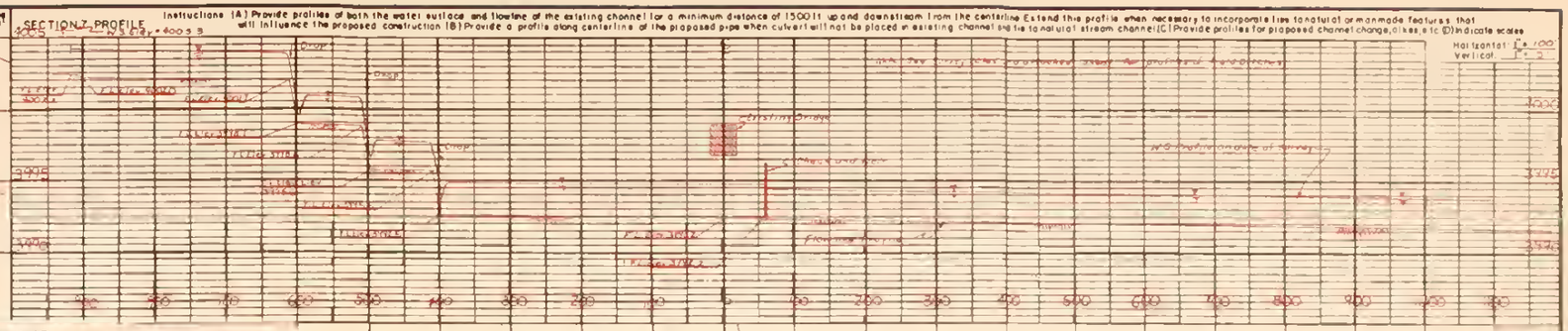
SECTION 6 CROSS SECTIONS Scale Horizontal 1" = 5' or as indicated ⊖
Vertical 1" = 5' or as indicated ⊖

Instructions Note, cross-sections should embody the following general characteristics. (1) Normal to channel, (2) Section extended to extend well above the maximum possible flood, (3) Vegetation described and accurately located, (4) Elevation differences of 6" or greater defined, (5) Use scale of 1"=5' vertical and horizontal unless there is an extensive flood plain In this case, a smaller horizontal scale may be used so as to define the flood plain and low water channel The low water portion should also be plotted again using a larger scale
(A) Provide typical section downstream from all proposed structures (B) Provide cross section at approximate construction limits upstream and downstream from all proposed crossings (C) Provide section under existing bridges to include substructure details, spill-slopes, channel, and high water marks (D) Provide typical section of any irrigation ditches, etc that will be affected by the construction (E) Indicate location of each section in Section 3 on 8 (F) Photos of each section to be taken and submitted to this office



SECTION 7 PROFILE

Instructions (A) Provide profiles of both the water surface and flowline of the existing channel for a minimum distance of 1500 ft up and downstream from the centerline Extend this profile when necessary to incorporate flow to natural or manmade features that will influence the proposed construction (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and tie to natural stream channel (C) Provide profiles for proposed channel change, dikes, etc (D) Indicate scales Horizontal 1"= 100' Vertical 1"= 5'


Existing Bridge
Low Chord Elev 3994.6
Flowline
Flowline
Flowline

FORM HYD 1 Example No 7 Simple Irrigation

MONTANA DEPT OF HIGHWAYS

Survey Data for Design of Waterways

Project Walla Swinger Springs East No F-6411
Stream Name Brown's Ditch Sta 39+30
County Meagher
Surveyed By R. Zollman Date 12-15-72

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION

GENERAL INSTRUCTIONS

1 Fill out all blanks carefully, giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples
2 Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing
3 Comments of local residents will aid in filling out much of this information The division fob may be of some help when filling out Section 3
4 The ditch rider, farmer, or ditch company should be contacted when filling out Section 4 Attach any right-of-way agreements if they have been made
5 Submit all survey notes with this sheet
6 Submit photographs of all channel and overbank areas and all existing structures Be sure they are well labeled Indicate the location and orientation of all photographs with an arrow (▷) in Section 8

SECTION 1 WATERSHED DATA

Estimated Drainage Area _____ Acres or Sq Miles
Area not contributing to runoff _____
Comment on land use or cover _____

Floating Debris None ☐, Light ☐, Medium ☐, Heavy ☐
Other ☐, Quantity of Debris _____
Ice Light ☐, Moderate ☐, Severe ☐.
Unusual Characteristics _____

Elev of water on date of survey _____
Elev of low water _____, normally dry ☐
Elev of high water _____, date occured _____
Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☐, Spring runoff ☐
Will ponding of water upstream cause damage to buildings or other property _____ If so what elev will water be allowed to reach _____
Should crossing be designed for fish passage _____

SECTION 2 EXISTING STRUCTURE

A Culvert Size 24", Type CSP Sq Ends
Condition Good, Length 39
B Bridge Type _____
No of spans _____, Length of each span _____
Clearance _____
Condition _____
C Approx distance above or below site 10' downstream
High water mark elev _____
Historical adequacy Adequate
Comments See photos for details of turnout and division box

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? No, is channel stable ☑, degrading ☐, aggrading ☐, unknown ☐ Is riprap or bank protection necessary? No
Are the following material available locally
Riprap Yes, Type B, Filter Material No 1 Yes, No 2 Yes
Is water or soil alkaline No, acidic No, or sulphates present No
Comments _____

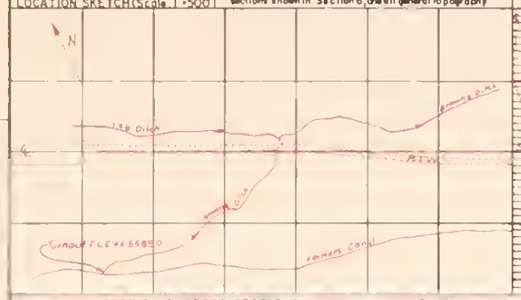
SECTION 4 IRRIGATION DATA

Name of ditch Browns Ditch
Owner Tom Brown
Address of ditch company Box to 2 mi N Swinger Springs
Ditch capacity 40 cfs or gpm Slope 003', Water Depth 1.5, Bottom width 2.0', Side Slopes 1:1, Total Depth 2.5'
Does ditch carry flood water also? No Flow line elevations of existing structure, inlet 5581.3 outlet 5581

COMMENTS _____

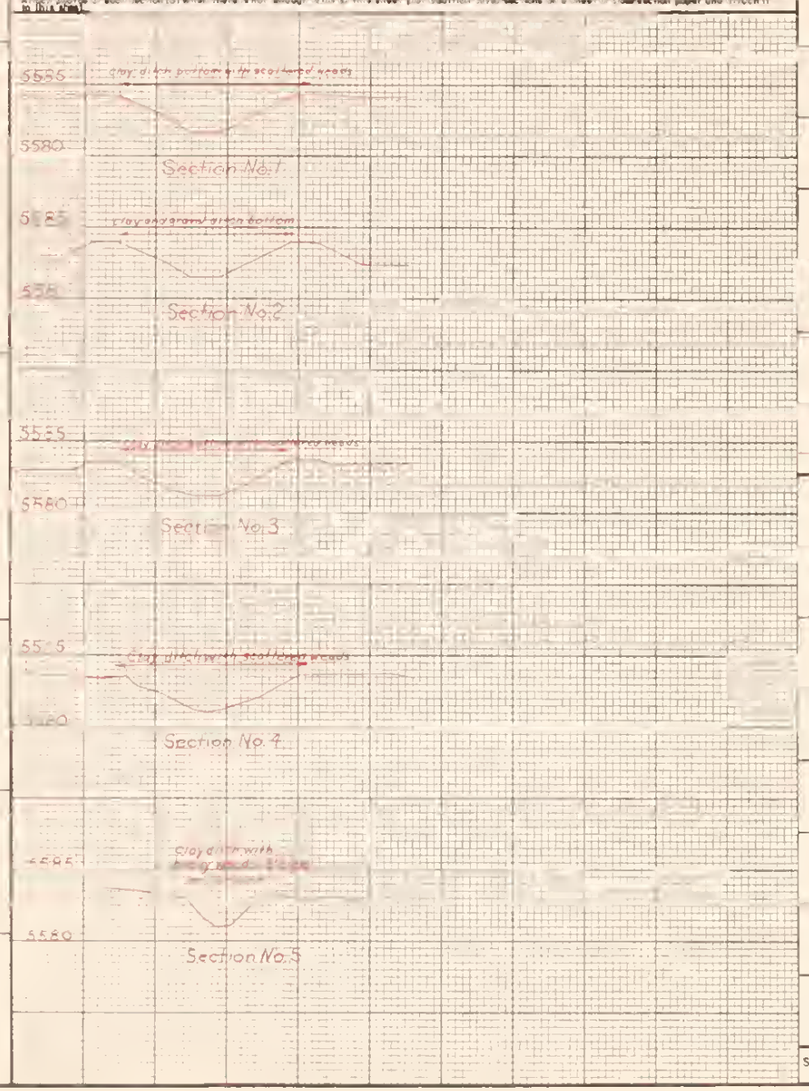
SECTION 5 LOCATION SKETCH (Scale 1"=500')

Instructions Show ℄ of survey, north arrow, general course of stream, existing structures, location of pit/channel cross-sections shown in Section 6, and all general topography



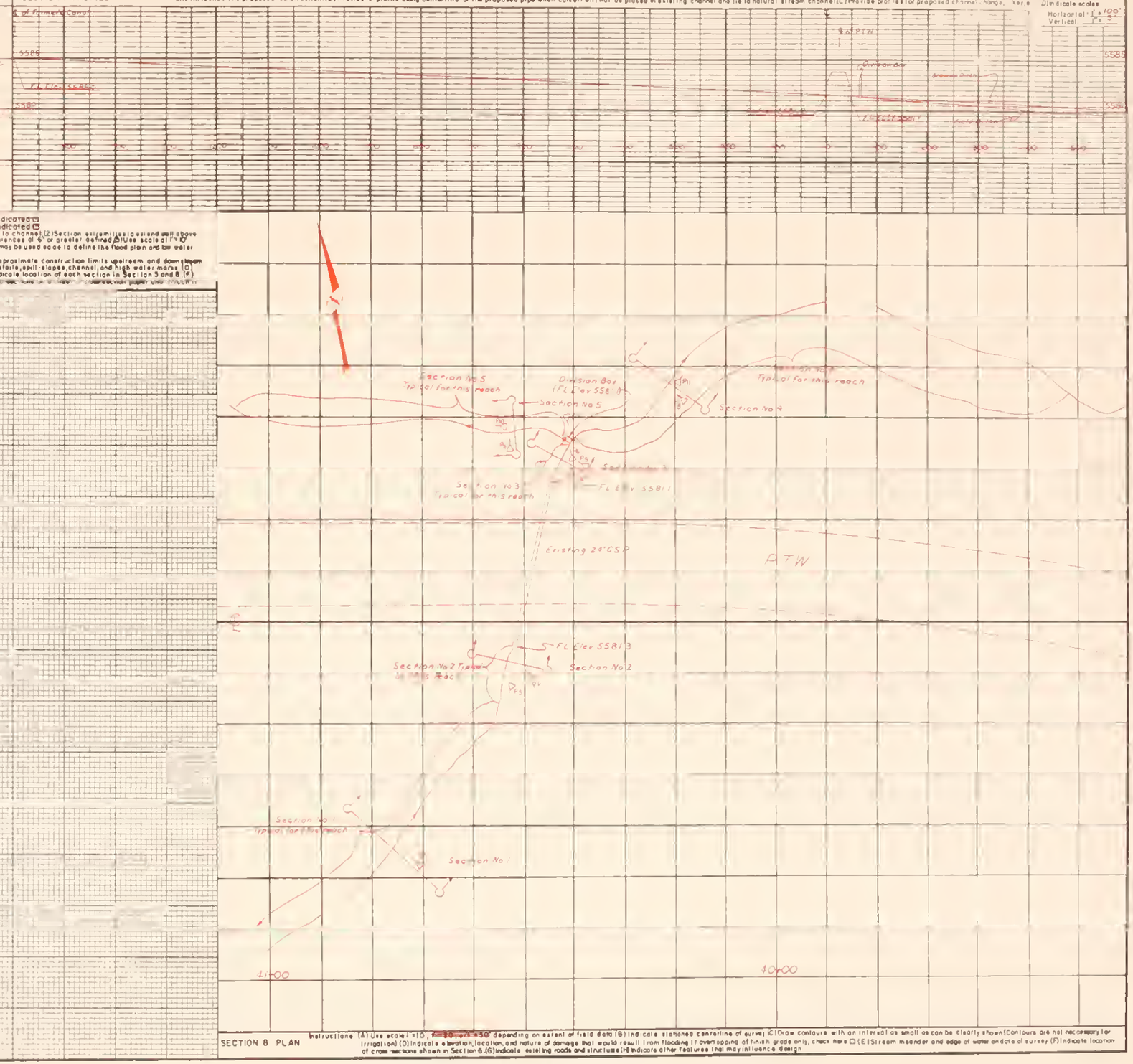
SECTION 6 CROSS SECTIONS Scale Horizontal 1"= 5' or as indicated ☐
Vertical 1"= 5' or as indicated ☐

Instructions Note: cross-sections should embody the following general characteristics: (1) Normal to channel (2) Section extended to and well above the maximum possible flood, (3) Vegetation described and accurately located (4) Elevation differences of 6" or greater defined (5) Use scale of 1"=10' vertical and horizontal unless there is an extensive flood plain In this case a smaller horizontal scale may be used as one to define the flood plain and low water channel The low water portion should also be plotted again using a larger scale
(A) Provide typical section downstream from all proposed structures (B) Provide cross-section at approximate construction limits upstream and downstream from all proposed crossings (C) Provide section under existing bridges to include substructure details, spill-slopes, channel, and high water marks (D) Provide typical section of any irrigation ditches, etc that will be affected by the construction (E) Indicate location of each section in Section 5 and 8 (F) A [illegible] in this sheet



SECTION 7 PROFILE

Instructions (A) Provide profiles of both the water surface and flowline of the existing channel for a minimum distance of 1500 ft up and downstream from the centerline Extend this profile when necessary to incorporate ties to natural or manmade features that will influence the proposed construction (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and tie to natural stream channel (C) Provide profiles for proposed channel change, ditch, etc (D) Indicate scales Horizontal 1"= 100' Vertical 1"= 5'



SECTION 8 PLAN

Instructions (A) Use scale 1"=10', 1"=20', or 1"=50' depending on extent of field data (B) Indicate stationing centerline of survey (C) Draw contours with an interval as small as can be clearly shown (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that would result from flooding If overtopping of finish grade only, check here ☐ (E) Stream meander and edge of water on date of survey (F) Indicate location of cross-sections shown in Section 6 (G) Indicate existing roads and structures (H) Indicate other features that may influence design

FORM HYD 1

MONTANA DEPT OF HIGHWAYS

Survey Data for Design of Waterways

Project _____ No _____

Stream Name _____ Sta _____

County _____

Surveyed By _____ Date _____

FOR DRAINAGES OF ONE SQUARE MILE OR LARGER AND ALL IRRIGATION

GENERAL INSTRUCTIONS

1. Fill out all blanks carefully giving all information obtainable See Section 2 of the Hydraulics Manual for more detailed instructions, discussions, and examples
2. Make any comments or provide any additional information that you feel may be pertinent to the design of this crossing
3. Comments of local residents will aid in filling out much of this information The division lab may be of some help when filling out Section 3
4. The ditch rider, farmer, or ditch company should be contacted when filling out Section 4 Attach any right-of-way agreements if they have been made
5. Submit all survey notes with this sheet
6. Submit photographs of all channel and overbank areas and all existing structures Be sure they are well labeled Indicate the location and orientation of all photographs with an arrow(▷) in Section 8

SECTION 1 WATERSHED DATA

Estimated Drainage Area _____ Acres or Sq Miles

Area not contributing to runoff _____

Comment on land use or cover _____

_____

Floating Debris None ☐, Light ☐, Medium ☐, Heavy ☐

Other ☐, Quantity of Debris _____

Ice Light ☐, Moderate ☐, Severe ☐,

Unusual Characteristics _____

_____

Elev of water on date of survey _____

Elev of low water _____, normally dry ☐

Elev of high water _____, date occured _____

Cause Backwater from ice ☐, Backwater from Construction ☐, Cloudburst ☐, Spring runoff ☐

Will ponding of water upstream cause damage to buildings or other property _____ If so what elev will water be allowed to reach _____

Should crossing be designed for fish passage _____

SECTION 2 EXISTING STRUCTURE

A Culvert Size _____, Type _____

Condition _____, Length _____

B Bridge Type _____

No of spans _____, Length of each span

_____, _____, _____, _____

Clearance _____

Condition _____

C Approx distance above or below site _____

High water mark elev _____

Historical adequacy _____

_____

Comments _____

SECTION 3 EROSION AND GEOLOGY DATA

Do banks or bed show scour? _____, Is channel stable ☐, degrading ☐, agrading ☐, unknown ☐ Is riprap or bank protection necessary? _____

Are the following material available locally

Riprap _____, Type _____, Filter Material No 1 _____, No 2 _____

Is water or soil alkaline _____, acidic _____, ore sulphates present _____

Comments _____

SECTION 4 IRRIGATION DATA

Name of ditch _____

Owner _____

Address of ditch company _____

Ditch capacity _____, Slope _____, Water Depth _____, Bottom width _____, Side Slopes _____, Total Depth _____

Does ditch carry flood water also? _____ Flow line elevations of existing structure, inlet _____ outlet _____

COMMENTS _____

SECTION 5 LOCATION SKETCH (Scale, 1"=500')

Instructions Show ℄ of survey, north arrow, general course of stream, existing structures, location of all channel cross sections shown in Section 6, and all general topography.

SECTION 6 CROSS SECTIONS Scale Horizontal 1" = ' or as indicated ☐
Vertical 1" = ' or as indicated ☐

Instructions Note, cross sections should embody the following general characteristics, (1) Normal to channel (2) Section sufficiently wide and well above the maximum possible flood, (3) Vegetation described and accurately (4) located, (4) Elevation differences of 6" or greater defined (5) Use scale of 1"= 10' vertical and horizontal unless there is an extensive flood plain In this case, a smaller horizontal scale may be used so as to define the flood plain and low water channel The low water portion should also be plotted again using a larger scale

(A) Provide typical section downstream from all proposed structures (B) Provide cross-section at approximate construction limits upstream and downstream from all proposed crossings (C) Provide section under existing bridges to include substructure, debris, spill-slopes, channel, and high water marks (D) Provide typical section of any irrigation ditches etc that will be affected by the construction (E) Indicate location of each section in Section 5 and B (F) Number each section and sheet (Graph paper sections and sheets of cross-section paper and attach it to this sheet)

SECTION 7 PROFILE

Instructions (A) Provide profiles of both the water surface and bottom of the existing channel for a minimum distance of 1500 ft up and downstream from the centerline Extend this profile when necessary to incorporate ties to natural or manmade features that will influence the proposed construction (B) Provide a profile along centerline of the proposed pipe when culvert will not be placed in existing channel and tie to natural stream channel (C) Provide profiles of proposed channel changes, ditches, etc (D) Indicate scales Horizontal 1" = Vertical 1" =

SECTION 8 PLAN

Instructions (A) Use scale of 1"=10', 1"=20', or 1"=50' depending on extent of field data (B) Indicate stationed centerline of survey (C) Draw contours with an interval as small as can be clearly shown (Contours are not necessary for irrigation) (D) Indicate elevation, location, and nature of damage that would result from flooding (if overtopping of finish grade only, check here ☐) (E) Stream meander and edge of water on date of survey (F) Indicate location of cross-sections shown in Section 6 (G) Indicate existing roads and structures (H) Indicate other features that may influence design

II-26 RIGHT-OF-WAY SURVEYS

26.00 General

The primary concern in making right-of-way surveys is that enough information is provided on the location of land subdivision and property ownership lines. This concern includes the accuracy with which centerline bearings are determined. These factors bear directly on the development of adequate right-of-way plans and on the legal property descriptions prepared from these plans.

State laws pertaining to land subdivision contain stringent surveying and platting requirements. The Department of Highways has been fortunate to have been specifically exempt from these requirements with regard to the transfer of land acquired for highway purposes. Our exemption is based on a separate legislation (R.C.M. 32-2413; Section 4, Chapter 500, L. 1973), which allows the transfer of land to the Department by reference to recorded plans. If careful attention is not given to assure that accurate and complete survey information is provided for the development of these plans, we foresee the possibility of losing our exempt status and being required to survey the boundaries of each property from which right-of-way is to be acquired. The following guidelines are set forth that we might preclude this possibility.

26.01 Ties to Section Lines and Subdivision Lines (See Figures 26-1 through 26-7)

A. It is desirable that ties to section corners and quarter corners be made at each intersection of the highway project centerline. Ties that should be made are shown in Figures 26-1 through 26-3.

All distances and angles shall be shown in the notes, as well as any additional information that is necessary to furnish a clear and concise sketch of the right-of-way situation.

B. Diligent search should be made for any existing section corners and quarter corners, but in the event none can be found, a minimum number of section corners and quarter corners should be re-established as necessary to provide section line ties. Corners shall be re-established in accordance with the regulations and methods for re-establishing lost or obliterated corners set forth in the Manual of Surveying Instructions, U.S. Department of Interior, Bureau of Land Management; and recorded in accordance with the Corner Recordation Act of Montana. (See Article 28.01 of this manual)

C. Ties should also be made to one-sixteenth corners whenever any are found in place.

D. Ties should be made to corners on boundary lines of homestead entry surveys, mineral surveys, mining claims, and other surveyed, platted, and recorded land subdivision, as follows:

1. Where the boundary line(s) intersect the highway centerline.
2. Where the boundary line(s) do not intersect the highway centerline but where one or more property corners are located:
   a. Within 150 ft. of the centerline of a Primary or Secondary Highway.
   b. Within 300 ft. of the median centerline of an Interstate Highway.

c. Within the limits of anticipated right-of-way.

3. Where appropriate, corners to which ties are made should be identified by number.

4. Where land is subdivided into blocks and lots, ties should be made to block, lot or subdivision corners, or to street intersection monuments.

5. It is not intended that all corners of each such subdivision tract be located and tied, but a sufficient number of corners should be located or re-established so that pertinent property lines can be determined.

E. Ties to land boundary lines should consist of the following:

1. The survey station of the point at which the boundary line intersects the highway centerline. If the boundary line intersects the centerline on a curve, a tie should also be made to the intersecting point on the semi-tangent. See Figure 26-6.

2. The angle of intersection between the land boundary line and highway centerline and semi-tangent.

3. The distance from the point of intersection of the boundary line and highway centerline and semi-tangent to located or re-established corner monuments.

4. Where two or more monumented corners are located on an intersecting boundary line, the distance should be given from the centerline to each corner.

5. Whenever more than one tie is made to the same corner along two different locations, all three of the interior angles should

be read and recorded in the survey notes so that a closure can be proven.

F. Accuracy of land corner ties should be within an allowable error not to exceed a ratio of 1 in 5000.

26.02 Bearings

The centerline bearings for each highway project should be determined by solar observations, observations on Polaris, or taken from the centerline bearing of an existing project which bearing had previously been determined by celestial observations.

26.03 Traverse Closure

Centerline traverses should be closed by bearing and station. Accuracy of closure should be within an allowable error not exceeding a ratio of 1 in 5000.

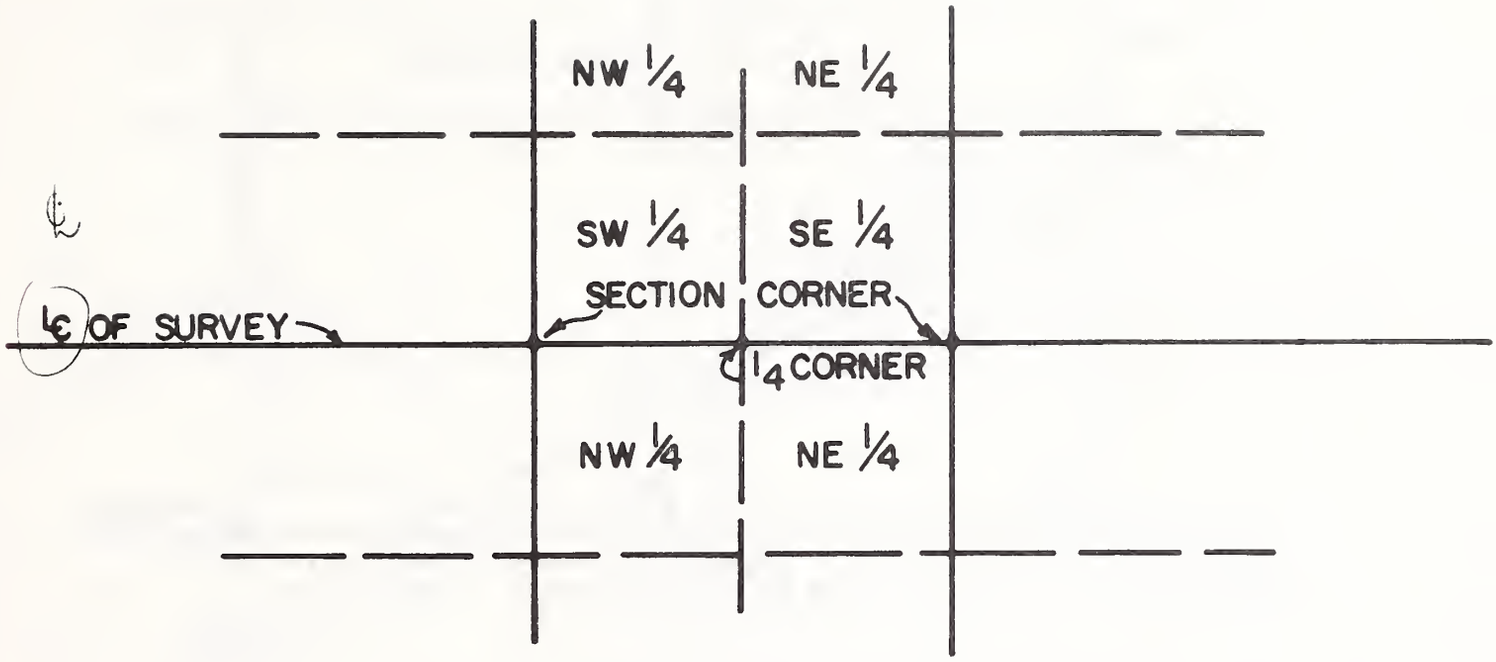


FIGURE 26-1. Typical situation when centerline follows or closely parallels section line. Show stations and plus to all section lines, quarter lines and property lines. Also, show distance from centerline right or left to section line.

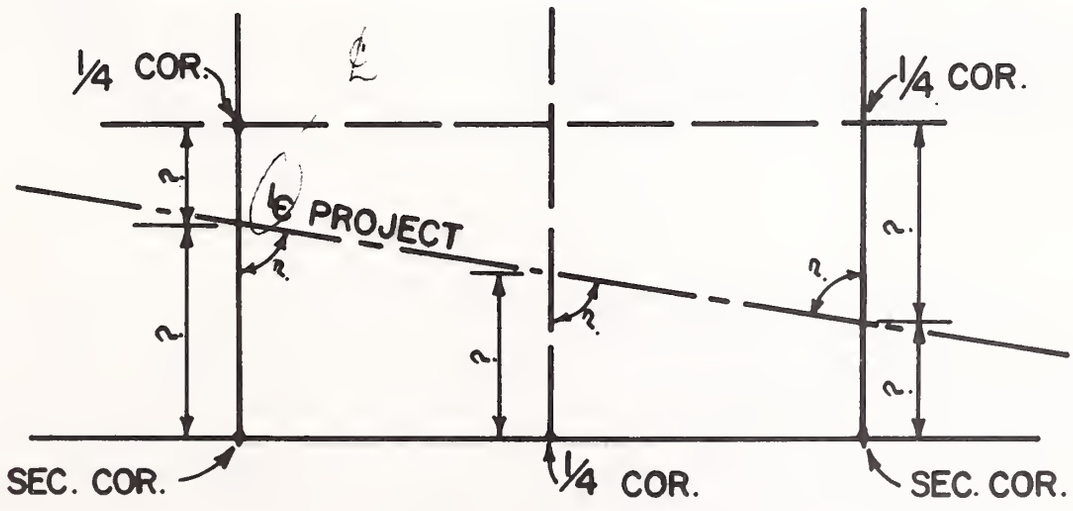


FIGURE 26-2. Typical situation when centerline cuts section on an angle. Show station and plus to all section lines, quarter lines, property lines, etc. and also show angles of intersection. Show distances to section corners and quarter corners as indicated.

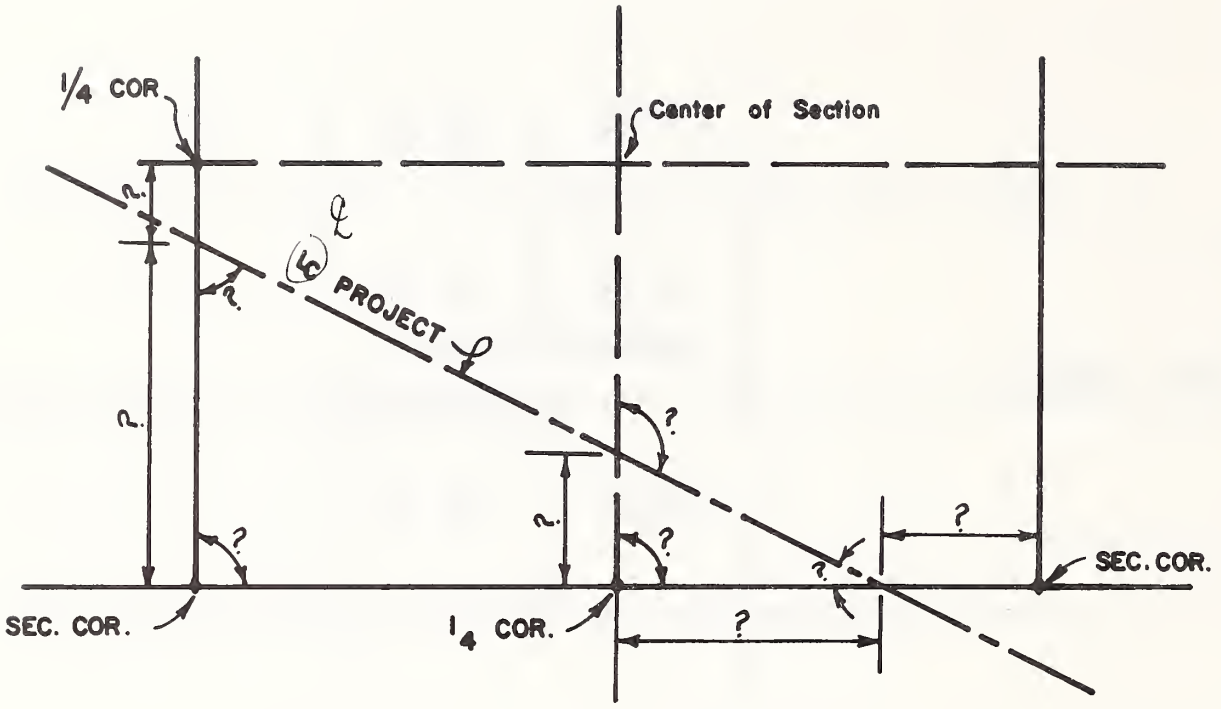
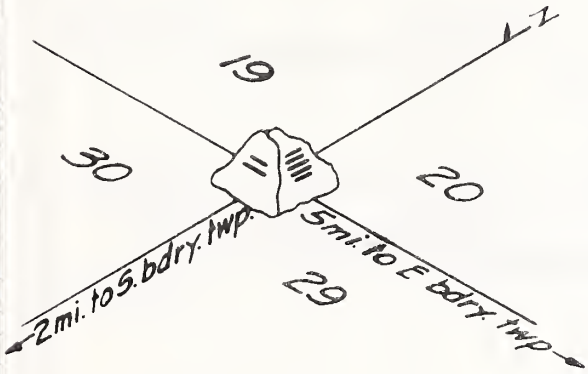


FIGURE 26-3 Typical situation when centerline cuts section leaving a triangular portion., Show station and plus to all section lines, quarter lines, and property lines, etc., and also show angles of intersection. Show distances to section corners and quarter corners as shown and give all angles as called for.

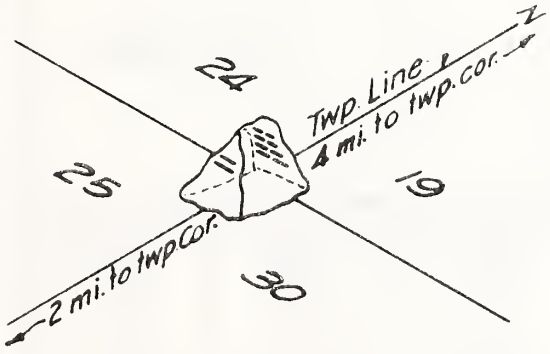
MARKS ON STONE MONUMENTS

Stone corners may be notched on edges, or grooved on faces depending on how stone is set in relation to cardinal points. For convenience, illustrations below show grooves.



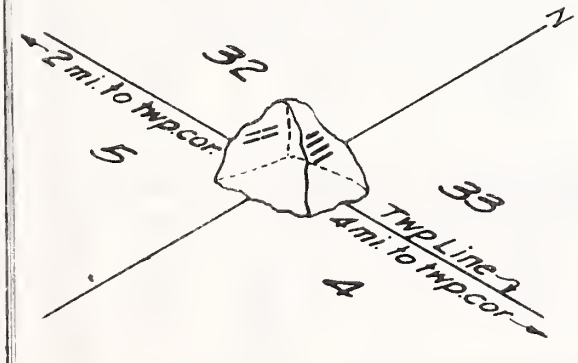
INTERIOR CORNER
COMMON TO FOUR SECTIONS

Number of grooves on East and South faces indicates number of miles from East and South boundaries of the township.



EXTERIOR CORNER
COMMON TO FOUR SECTIONS ON N.&S. TOWNSHIP LINE

Number of grooves on North and South faces indicate number of miles from corresponding township corners.



EXTERIOR CORNER
COMMON TO FOUR SECTIONS ON E.& W. TOWNSHIP LINE

Number of grooves on East and West faces indicates number of miles from corresponding township corners.

Where ties are to be made to land corners, the field party should have a copy of the U.S.G.L.O. notes pertaining to same.

The topography, description of corners and markings, bearing trees and courses contained therein are indispensable for identifying old corners.

For markings used in special cases such as closing corners, meander corners, witness corners, etc., see Manual of Surveying Instructions, U.S. Dept. of Interior, Bureau of Land Management.

All locators and R/W field men should be familiar with means of identifying corners and also with legal procedure for reestablishing lost and obliterated corners.

FIGURE 26-4

A SECTION OF LAND–640 ACRES

80 Chains – 320 Rods – 5280 Feet

40 CHAINS

7.92 inches are 1 link.
25 links are 1 rod.
4 rods or 100 links are 1 Chain.
A rod is 16 1/2 feet.
A pole is 16 1/2 feet.
A chain is 66 feet or four rods.
A mile is 320 rods, 80 chains or 5,280 feet.
An acre contains 43,560 square feet.
An acre contains 160 square rods.
An acre is 208.7 (plus) feet square.
An acre is 8 rods wide by 20 rods long, or any two numbers (of rods) whose product is 160.
Square feet X .000023= acres.
Square chains X 0.10= acres.
40 chains equals 160 rods or 2640 feet.

(160 ACRES)

20 CHAINS

(80 ACRES)

80 rods or 1320 feet

10 CHAINS

(20 ACRES)

40 rods or 660 ft.

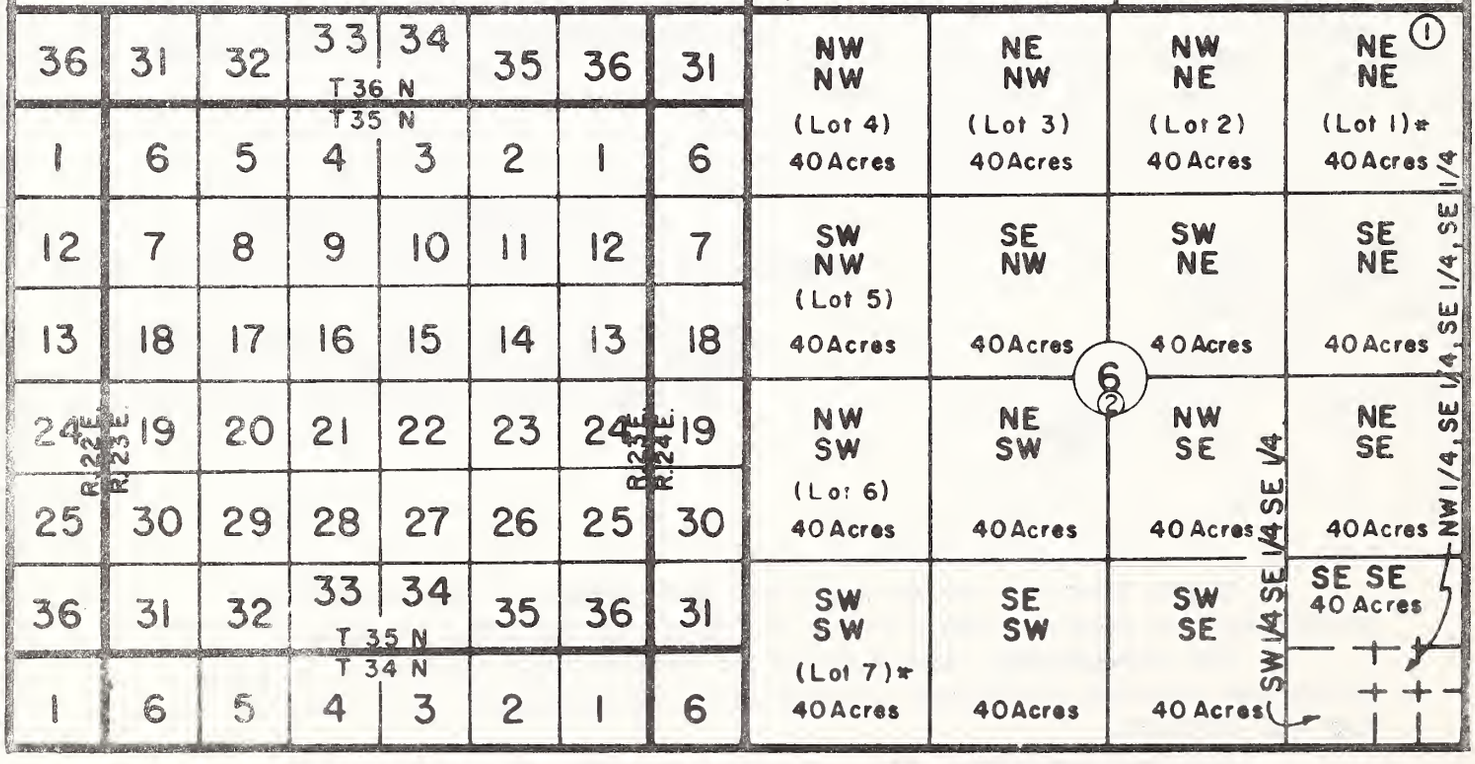
5 chains 5 acres 20 rods or 330 ft.

5 chains 5 acres 20 rods or 330 ft.

(10 ACRES) 40 rods or 660 ft.

(40 ACRES)

80 rods – 20 chains or 1320 ft.


36 31 32 33 34 35 36 31
T 36 N
T 35 N
1 6 5 4 3 2 1 6
12 7 8 9 10 11 12 7
13 18 17 16 15 14 13 18
24 19 20 21 22 23 24 19
25 30 29 28 27 26 25 30
36 31 32 33 34 35 36 31
T 35 N
T 34 N
1 6 5 4 3 2 1 6
R.22E
R.23E
R.23E
R.24E
NW NW (Lot 4) 40 Acres
NE NW (Lot 3) 40 Acres
NW NE (Lot 2) 40 Acres
NE NE (Lot 1)* 40 Acres
SW NW (Lot 5) 40 Acres
SE NW 40 Acres
SW NE 40 Acres
SE NE 40 Acres
NW SW (Lot 6) 40 Acres
NE SW 40 Acres
NW SE 40 Acres
NE SE 40 Acres
SW SW (Lot 7)* 40 Acres
SE SW 40 Acres
SW SE 40 Acres
SE SE 40 Acres
6
NW 1/4, SE 1/4, SE 1/4, SE 1/4
SW 1/4 SE 1/4 SE 1/4

Sectional Map of Township with Adjoining Sections.

Subdivisions of a Section

(1) It is common practice in Montana to write this NE 1/4 NE 1/4

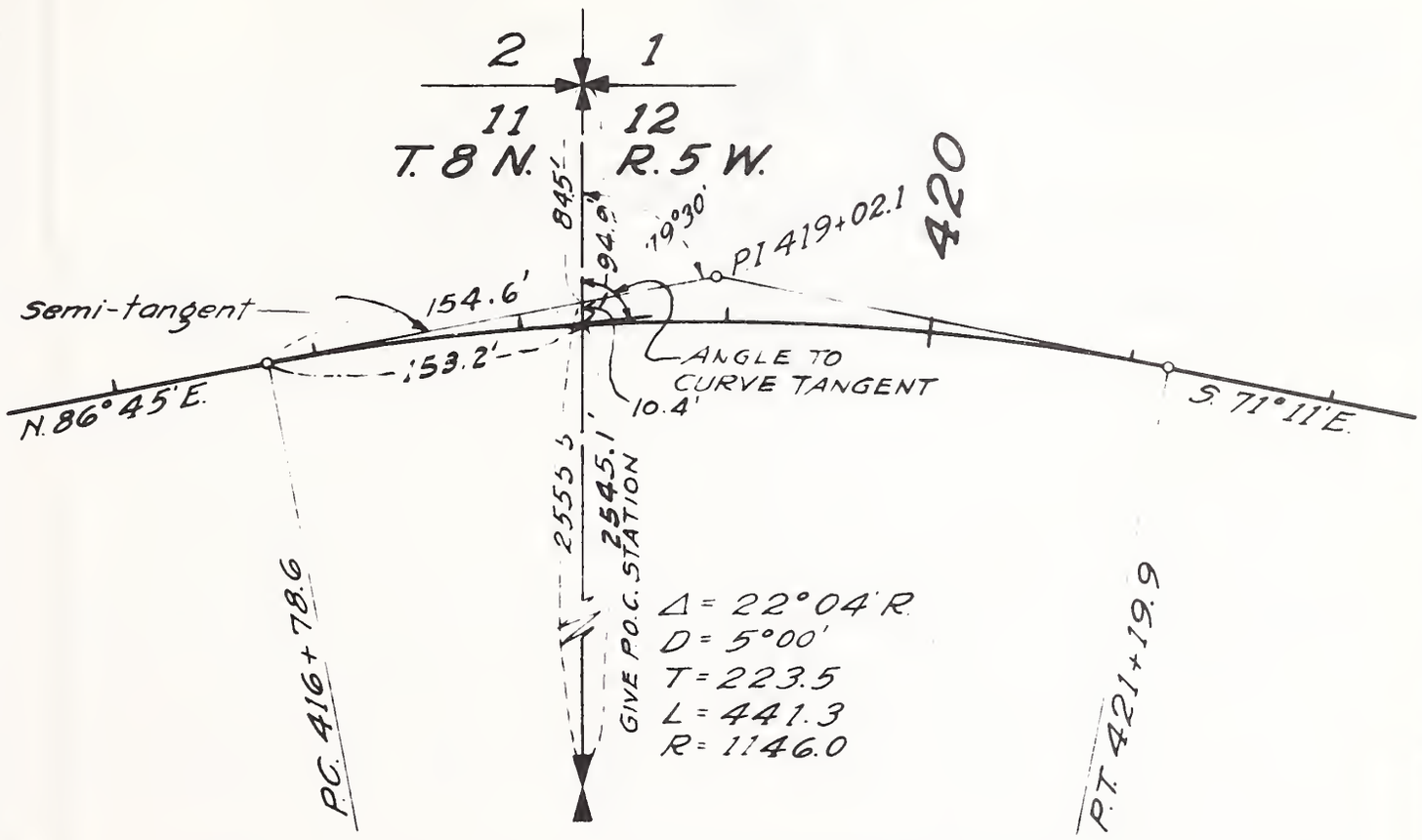
* Standard lots are usually along the north and/or west lines of a section or township and the acreage may be more or less than 40.

(2) Section 6

We would like to emphasize that these dimensions are not typical of the actual dimensions which have been established by original land surveys, but rather, they represent target values which frequently only approximate actual measurements.

FIGURE 26-5

TIE TO SECTION LINE ON CURVE



Describe in detail type of corner tied to.

TIE TO SECTION LINE ON TANGENT

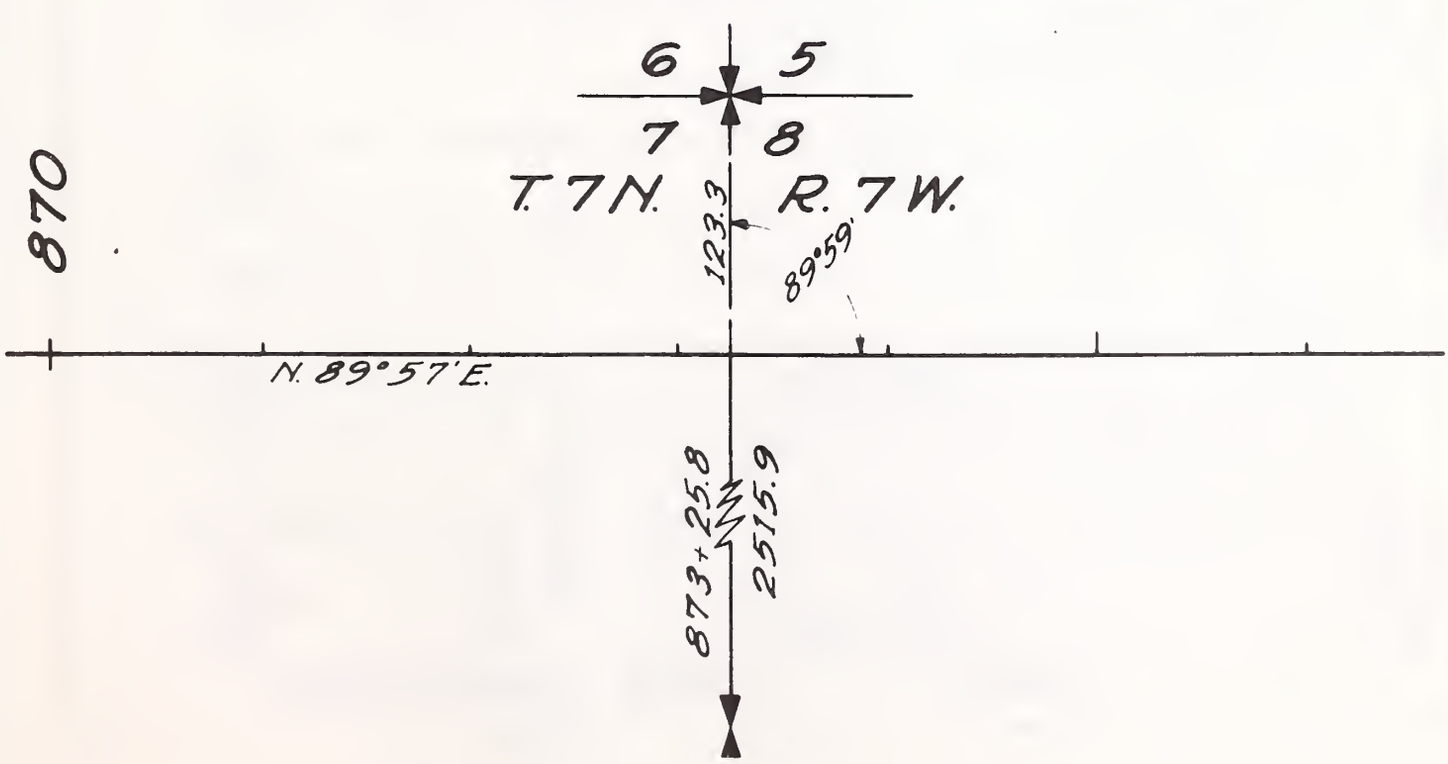
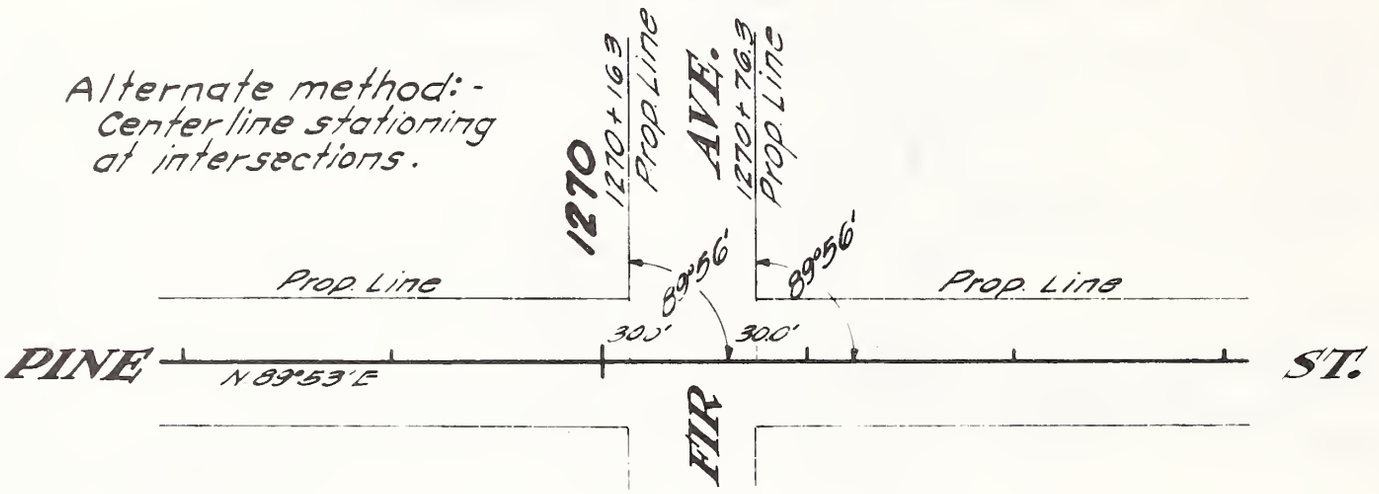


FIGURE 26-6

TIES TO MUNICIPALITY LINES



TIE TO CITY OR TOWN LIMITS

Legal description of city or town to be submitted with location survey notes.

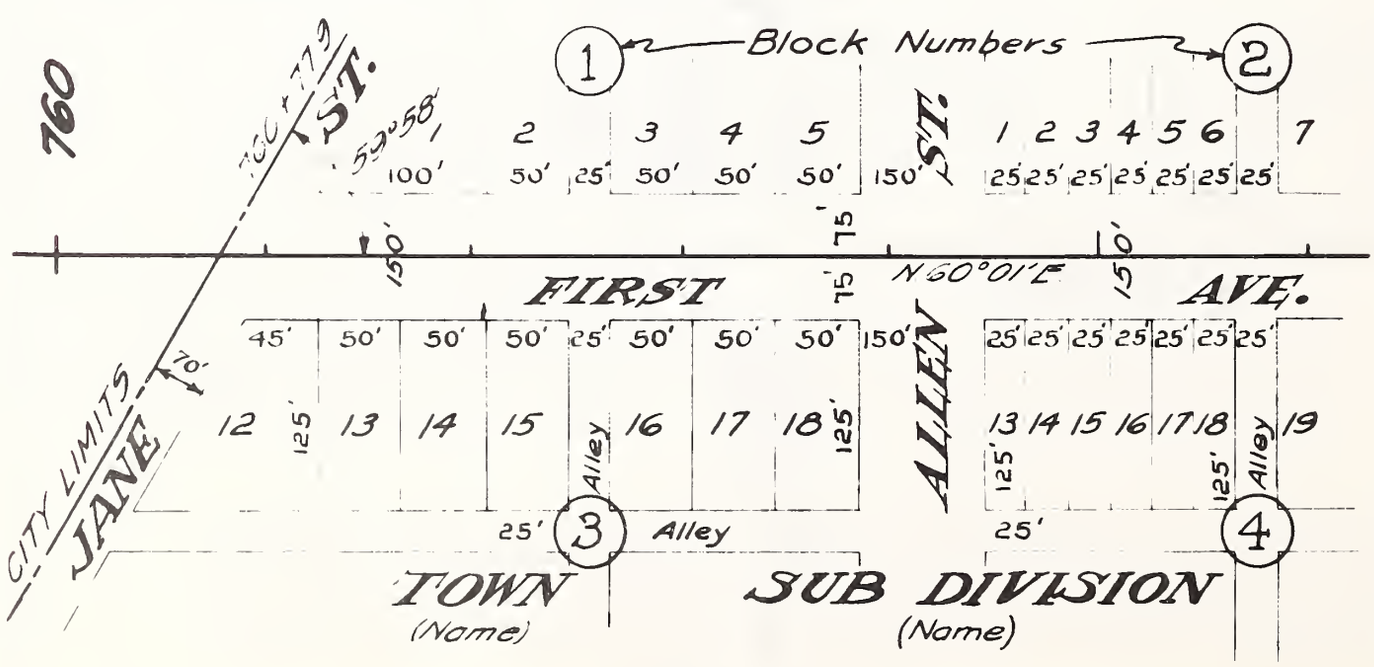


FIGURE 26-7

II-28 RELOCATION OF SURVEY MONUMENTS

28.00 Public Land Survey Corners

The "Corner Recordation Act of Montana," (R.C.M. 67-2001 through 2010) requires surveyors to reconstruct and perpetuate monuments of public land survey corners and to file information to locate the public land survey corners with the County Clerk and Recorder of the counties in which the corners are situated. The act is reprinted in its entirety in Article 28.01.

The following procedure shall be required to protect and perpetuate public land survey corners and information concerning the location of such corners. This information shall be on a form entitled, Certified Land Corner Recordation, and referred to as a "corner record".

A. Every public land survey corner and accessory to such corner used, or proposed to be used by a Department of Highways surveyor or survey crew shall be examined and reviewed with information available in the "corner records" of the County Clerk and Recorder's office in the County in which the corner is situated. The surveyor shall then determine if the "corner record" is substantially described in the County records on a Certified Land Corner Recordation for the specific land corner.

B. If the Certified Land Corner Recordation or "corner record" for the public land survey corner and accessory to such corner is properly reflected in the appropriate County, no additional information need be filed for record. The date of inspection and any appropriate comments shall be recorded in the Project Field Notes.

C. If the Certified Land Corner Recordation or "corner record" for the public land survey corner and accessories to such corner is not of public record in the appropriate County, a Certified Land Corner Recordation shall be prepared, completed, and filed for record in the County in which the corner is situated. The preparation, completion, and filing of Certified Land Corner Recordation shall apply to all public land survey corners and accessories to such corner whether re-established, re-monumented, restored, rehabilitated, perpetuated, or used as a control in any survey.

1. A copy of the Certified Land Corner Recordation form is included as Figure 28-1. Copies of the form should be available from the County Clerk and Recorder. Article 28.02 contains instructions for completing the form.
2. The Certified Land Corner Recordation may be signed on behalf of the Department of Highways by the survey party chief making the survey, and approved, signed, and sealed by the registered surveyor in responsible charge of the survey.
3. The Certified Land Corner Recordation shall be filed with the County Clerk and Recorder of the County or counties in which the corner is situated. It shall be filed within 90 days of the re-establishment or restoration of the corner. The filing fee for the Certified Land Corner Recordation shall be considered as a similar service to recording a townsite map of one (1) lot.

D. The surveyor shall reconstruct or rehabilitate the monument of a public land survey corner, and accessory to such corner so that the same shall

be left by him in such physical condition that it remains as permanent a monument as is reasonably possible and so that it may be reasonably expected to be located with greater ease in the future. Figure 28-2 shows a proper method of witnessing corners which may be destroyed by highway construction.

Remember that in order to properly relocate a lost or obliterated corner, the surveyor must be familiar with land laws regarding the subdivision of sections. Legal restoration of lost or obliterated monuments also requires a knowledge of the principles employed in the original survey.

Before running in section lines from found corners, the surveyor should check GLO plats. GLO plats should be referred to with special attention when the survey is along the North or West boundary of townships; along rivers, reservations, or mountain areas; or where original surveys were joined.

28.01 Corner Recordation Act of Montana

The following is a copy of the Corner Recordation Act of Montana. Paragraph numbering is as used in the Revised Codes of Montana.

67-2001. Corner recordation -- citation of act. This act may be cited as the "Corner Recordation Act of Montana."

67-2002. Purpose of act. It is the purpose of this act to protect and perpetuate public land survey corners and information concerning the location of such corners by requiring the systematic establishment of monuments and recording of information concerning the marking of the location of such public land survey corners and to allow the systematic location of other property corners, thereby providing for property security and a coherent

system of property location and identification of ownerships; and thereby eliminating the repeated necessity for re-establishment and relocations of such corners where once they are established and located.

67-2003. Definitions. Except where the context indicates a different meaning, terms used in this act shall be defined as follows:

(1) A "property corner" is a geographic point on the surface of the earth, and is on, a part of, and controls a property line.

(2) A "property controlling corner" for a property is a public land survey corner, or any property corner, which does not lie on a property line of the property in question, but which controls the location of one or more of the property corners of the property in question.

(3) A "public land survey corner" is any corner actually established and monumented in an original survey or resurvey used as a basis of legal description for issuing a patent for the land to a private person from the United States government.

(4) A "corner," unless otherwise qualified, means a property corner, or a property controlling corner, or a public land survey corner, or any combination of these.

(5) An "accessory to a corner" is any exclusively identifiable physical object whose spatial relationship to the corner is recorded. Accessories may be bearing trees, bearing objects, monuments, reference monuments, line trees, pits, mounds, charcoal-filled bottles, steel or wooden stakes, or other objects.

(6) A "monument" is an accessory that is presumed to occupy the exact position of a corner.

(7) A "reference monument" is a special monument that does not occupy the

same geographical position as the corner itself, but whose spatial relationship to the corner is recorded, and which serves to witness the corner.

(8) A "registered surveyor" is a surveyor who is registered to practice land surveying under the Montana Professional Engineers Registration Act and has a paid up license for that calendar year, or who is authorized under the Montana Professional Engineers Registration Act to practice land surveying.

(9) The "board" is the state board of registration for professional engineers and land surveyors.

67-2004. Filing of corner record required. A surveyor shall complete, sign, stamp with his seal, and file with the County Clerk and Recorder of the county where the corner is situated, a written record of corner establishment or restoration to be known as a "corner record" for every public land survey corner, and accessory to such corner which is established, re-established, monumented, re-monumented, restored, rehabilitated, perpetuated or used as control in any survey by such surveyor, and within ninety (90) days thereafter, unless the corner and its accessories are substantially as described in an existing corner record filed in accordance with the provisions of this act.

67-2005. Filing permitted as to any property corner. A surveyor may file such corner record as to any property corner, property controlling corner, reference monument or accessory to a corner.

67-2006. Form to be prescribed by board. The board shall by regulation provide and prescribe the information which shall be necessary to be

included in the corner record and the board shall prescribe the form in which such corner record shall be presented and filed.

67-2007. County Clerk shall receive, file, and cross reference.

(1) The County Clerk and Recorder of the county containing the corner shall receive the completed corner record and preserve it in a hardbound book. The books shall be numbered in numerical order as filed.

(2) The clerk shall number the forms in numerical order as they are filed.

(3) The book and page number in which the said corner record is filed shall be placed by the clerk near that same corner on a cross index plat which the clerk shall provide for such a purpose.

(4) The County Clerk and Recorder shall make these records available for public inspection during all usual office hours.

(5) For purposes of determining the filing fee hereunder, the corner record shall be considered as a similar service to recording a townsite map of one (1) lot.

67-2008. Surveyor must rehabilitate monuments. In every case where a corner record of a public land survey corner is required to be filed under the provisions of this act, the surveyor must reconstruct or rehabilitate the monument of such corner, and accessories to such corner, so that the same shall be left by him in such physical condition that it remains as permanent a monument as is reasonably possible and so that the same may be reasonably expected to be located with facility at all times in the future.

67-2009. Corner records to be certified. No corner record shall be filed unless the same is signed by a registered surveyor and stamped with his seal, or in the case of an agency of the United States government or the State of Montana the certificate may be signed by the survey party chief, making the survey and approved, signed and sealed by the registered surveyor in responsible charge of the agency.

67-2010. Filing of corner records on locations made before effective date. Corner records may be filed concerning corners established, re-established or restored before the effective date of this act.

28.02 Instructions to Surveyors for Completion of Certified Land Corner Recordation Forms

All the information in this article refers to the various sections of the corner recordation form which is copied as Figure 28-1.

A. Description of Corner Evidence found, and Original Record, (if known): This item will be used to describe the corner evidence found, and to compare this with the original record. The evidence found should be listed first, for example:

> Found underground remains of wood stake, about three (3) inches square, bottom eighteen (18) inches below ground (Record, four (4) inches wood stake), from which center of root hole of fallen forty-eight (48) inches pine bears N. seventy (70) degrees E., sixty-nine (69) links (Record, thirty (30) inches pine, N. sixty-seven (67) degrees E., seventy-one (71) links). Scribing is unmistakable, but cannot read it.

B. Description of Monument and Accessories Established to Perpetuate the Original Location of this Corner: This item will be used to describe the monuments and accessories being used to perpetuate the corner, for example:

> Through the remains of the rotted wood stake, I drove a two (2) inch by thirty (30) inches galvanized iron pipe twenty (20) inches into the ground, from which:
>
> 8 inch Douglas Fir bears S. 75 degrees E., 32 links, scribed, "S6, RM".
> 5 inch Pine bears S. 10 degrees W., 7 links, scribed, "S1, RM".

C. Sketch, with Course and Distance to Adjacent Corners if Determined in this Survey (May sketch or paste reproduction on reverse side): The purpose of this item is to show a sketch of your survey if no plat of your survey is made and filed for record. It will also be used to show adjacent corners and the method you used to re-establish a lost corner. It is very important to show the origin of your bearings and distances so that any surveyor can retrace your work.

D. Certification and Diagram of Corner: The certification is self-explanatory. The "Diagram of Corner" is a graphical representation of the corner recorded on the sheet, and should identify the sections, ranges and townships involved.

The Montana State Board of Registration for Professional Engineers and Land Surveyors wishes to emphasize that this corner record is an edited representation of your original notes, and after filing becomes a part of the public record.

This public record is admissible in court, while the surveyor's personal notes are seldom admissible unless he is there to interpret them.

Having an edited version of your notes a part of the public record helps the property owner because the corner you set attains a greater measure of legal status after the passage of time. The adjoining land owners are also helped because they can inspect the public record of that survey, and, if they agree with the findings, later point to the public record as proof of survey and monumentation.

The status of the Land Surveying profession will be greatly enhanced if surveyors are conscientious in their perpetuation of existing property corners, permanent monumentation of new corners, and the public filing of that information.

28.03 Witness Monuments for Corners

Corners that will be destroyed by highway construction should be witnessed, wherever possible, by four (4) monuments so that the original point can be located by intersection alone. Where the lay of the land or obstructions prohibit the intersection method, no less than two (2) monuments are to be used in tying the corner. The surveyor will be expected to exercise his best judgement in selecting the position for witness corners with a view to affording definite and convenient connections from the witness corners to the true point for the monument. Wherever possible place witness monuments one (1) foot inside right-of-way lines. Suggested methods of witnessing corners are sketched in Figure 28-2.

When the corner is in fill, witness the corner, cover it, and file a corner record per Article 28.02. Edited notes may accompany the recordation.

When the corner is in cut, reset the corner from the witness monuments, placing it at least twelve (12) inches below the road surface and record the depth in the survey notes. File a corner record as outlined in this chapter.

28.04 National Geodetic Survey Monuments

Copies of recent National Geodetic Survey Literature on geodetic survey mark preservation are included here. The reader is asked to refer to the Construction Surveys section (page 30-21) for a more complete discussion of this subject.

MID-CONTINENT FIELD DIRECTOR
COAST AND GEODETIC SURVEY, ESSA
ROOM 1436, FEDERAL BUILDING
601 EAST 12th STREET
KANSAS CITY, MISSOURI 64106

U S. DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY
WASHINGTON 25 D C

INTRODUCING MARVIN MARKER

My name is Marvin Marker. I belong to an extremely large family of bronze station markers which are property of the U. S. Coast and Geodetic Survey. Because of my 150 year s longevity I was chosen to solicit your help in a serious family problem.

Our problem is the same as that faced by people throughout the world today — SURVIVAL! Yet our concern, apart from man's, is not because of the present world situation. Our chances of survival are slim regardless of the world's condition! And they are getting slimmer all the time! That's why I am appealing to you!

Lately our lineage has suffered terrifically because of premature deaths. Last year, thousands of Markers met with ill-fated deaths. Hundreds were mistreated, abused, uprooted and thrown away. Some were even brutally murdered. Few, I am sorry to say, ever die comfortably of old age.

Although I am emotionally involved as a member of the family, I can't help but think that people, too, would become a bit emotional if they knew the terrific expense involved in replacing us. Someone told me that the Government spends thousands of dollars each year just replacing unfortunate Markers (Boy! That sounds like an awful lot of the people s money, since they're always complaining about not having enough!!) And yet I m sure that if people were made aware of a few things about us, 95% of these losses could be prevented.

From time to time we suffer through maliciousness. Halloween, without fail, finds pranksters attempting in various ways to pry us up. Souvenir hunters, too, frequently steal us for use as paperweights, bookends, or just for the thrill of an unusual memento. The laugh will be on them if they are ever caught, though! Imprisonment or a $250 fine hardly seems worth the thrill they receive from such frolicking.

Our biggest enemy, however, is the man behind the bulldozer or grader. Brother! On more than one occasion in my lifetime I have had to do some fast praying for fear that I would follow some of my relatives to the grave — an unfortunate victim of a crushed disk! I thank my lucky stars that the present owner of the property on which I live knows all about me, and my value to surveyors and engineers. He takes special precautions to see that I stay healthy, and that no man or machine damages me.

It s because of these well informed, thoughtful people who are careful to watch for us and for our distress signs, that many Markers live long, useful lives. Actually, we are supposed to be immortal. But, some of the family have died of old age, erasion or sedimentation because the services of a professional engineer were not engaged soon enough to save them.

Please, won t you perform a valuable service to your country and community by helping Markers live a normal life span? Engineers, businessmen, housewives, students, — Just about every citizen can help!

Remember these facts!

(1) Never remove a survey marker. Once this is done, the value of it is lost entirely, and replacement is costly.

(2) If there is construction going on in your area and you notice a survey mark which appears to be in the way, call it to the attention of the surveyor in charge to insure that he is aware of it.

(3) If you see a survey mark which appears to be susceptible to damage of any kind or which seems to be undergoing erasion or other old-age ailments, flag it by driving stakes nearby and marking them with red ribbon, cloth, or plastic.

(4) In all cases, submit a report of your findings to The Director, Coast and Geodetic Survey, U S Department of Commerce, Washington 25, D C.

When you respond to this appeal, you will be performing a tremendous service for your Government. And as for me and the Marker Family, you will be helping to achieve longer and better lives for Markers all over the World.

Thanks from the entire family!

HELP PRESERVE SURVEY MARKERS

KNOW THESE MARKERS

BENCH
(Old Type)

BENCH
(New Type)
Two Bench Marks Consolidated

BENCH
(Old Type)

TRAVERSE

TRIANGULATION

GRAVITY
(Old Type)

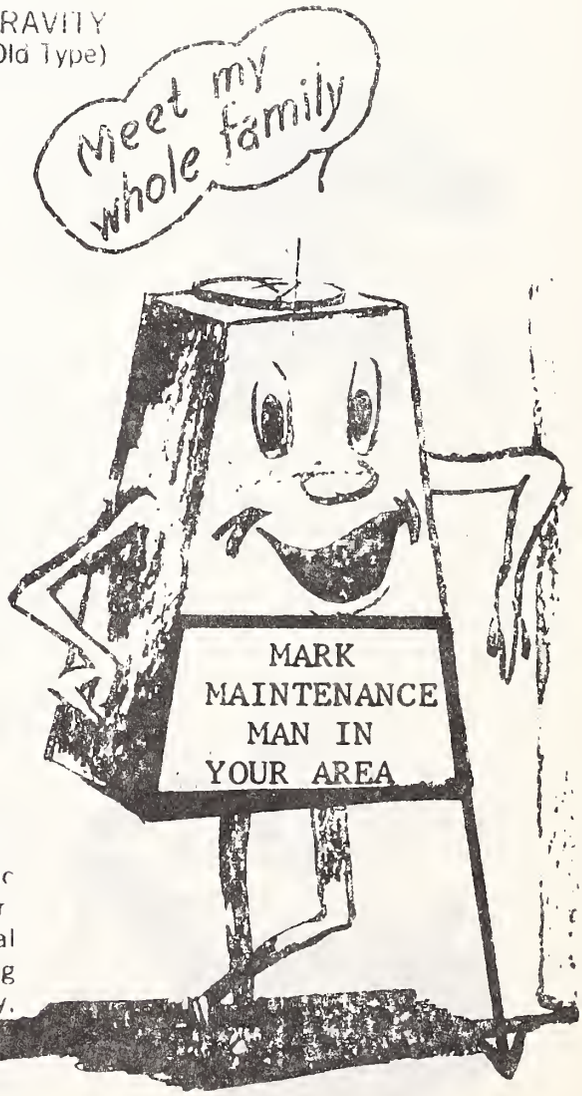
GRAVITY
(New Type)

TOPOGRAPHIC

AZIMUTH

REFERENCE

MAGNETIC



FACE LEGENDS

Standard bronze station marks of the Coast and Geodetic Survey that are set in concrete or bedrock to serve as a permanent mark for the particular station it represents. Additional information concerning these marks may be obtained by writing to the Director, United States Coast and Geodetic Survey.

MID-CONTINENT FIELD DIRECTOR
COAST AND GEODETIC SURVEY, ESSA
ROOM 1436, FEDERAL BUILDING
601 EAST 12th STREET
KANSAS CITY, MISSOURI 64106
Phone: 816-374-3156

OR

MR. JAMES T. STAPLETON
c/o DIRECTOR, PACIFIC MARINE CENTER
COAST & GEODETIC SURVEY
1801 FAIRVIEW AVE. EAST

FIGURE 28-1. CERTIFIED LAND CORNER RECORDATION

Description of corner evidence found, and original record (if known)

Description of monument and accessories established
to perpetuate the original location of this corner:

Date of work_____

Sketch, with course and distance to adjacent corners if determined in this survey. (May sketch or paste reproduction on reverse side.)

Diagram of Corner:

Surveyor's Seal

I,_____
certify that the information shown herein is true and correct.

N.

_____
Signature of Ground Party Chief

I,_____
certify that I have carefully performed or reviewed the work done on the diagrammed corner as reported on this recordation form and approve the same.

= Corner recorded on the sheet.

_____
Signature of Surveyor

_____
Registration Number

Office of Clerk and Recorder, County of _____

This "corner record" was filed for record on the _____day of_____19___,

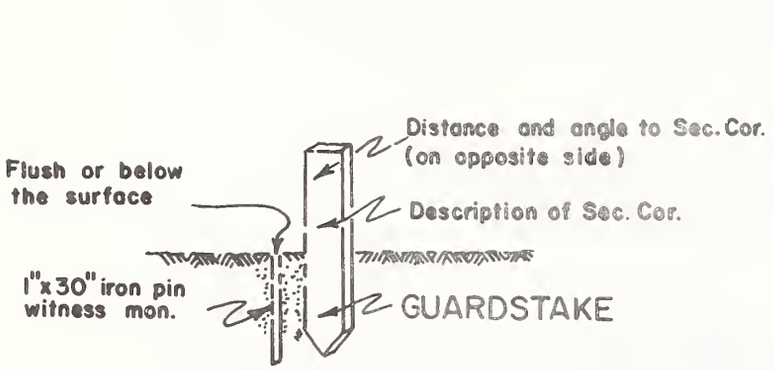
was noted on the cross-index plat and is assigned page No._____,

in book No._____.

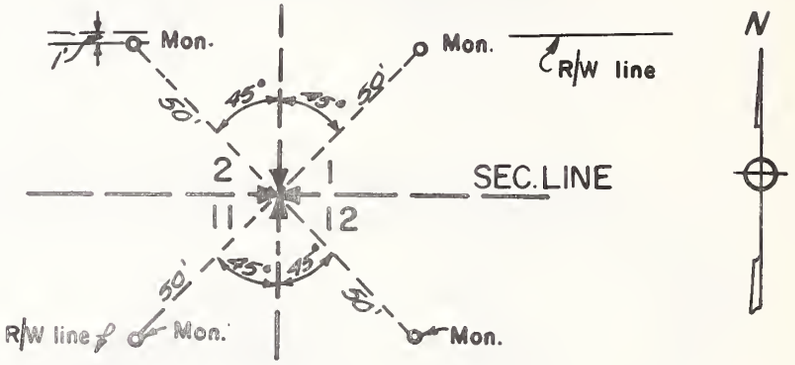
_____
County Official

Cross Index No._____T_____R_____Mer.

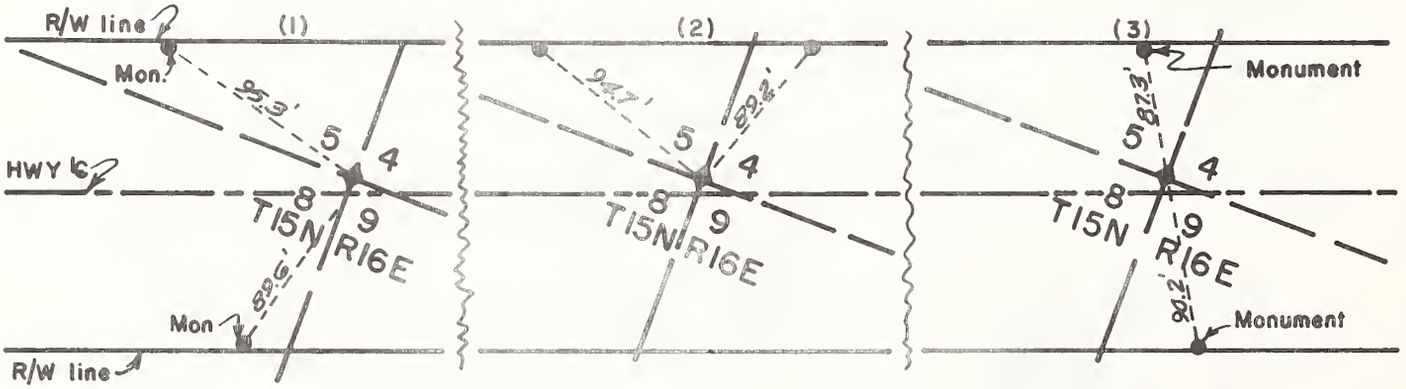
FIGURE 28-2 METHODS OF WITNESSING CORNERS THAT WILL BE DESTROYED BY HIGHWAY CONSTRUCTION


Distance and angle to Sec. Cor. (on opposite side)
Flush or below the surface
Description of Sec. Cor.
1"x30" iron pin witness mon.
GUARDSTAKE

ACCEPTABLE MONUMENTATION



PREFERRED WITNESSING



Suggested Methods of Witnessing a Corner where four monuments are not practicable. Methods 1 and 2 are preferred.

SURVEYING MANUAL

* * * * * * * * * * * * * * * *

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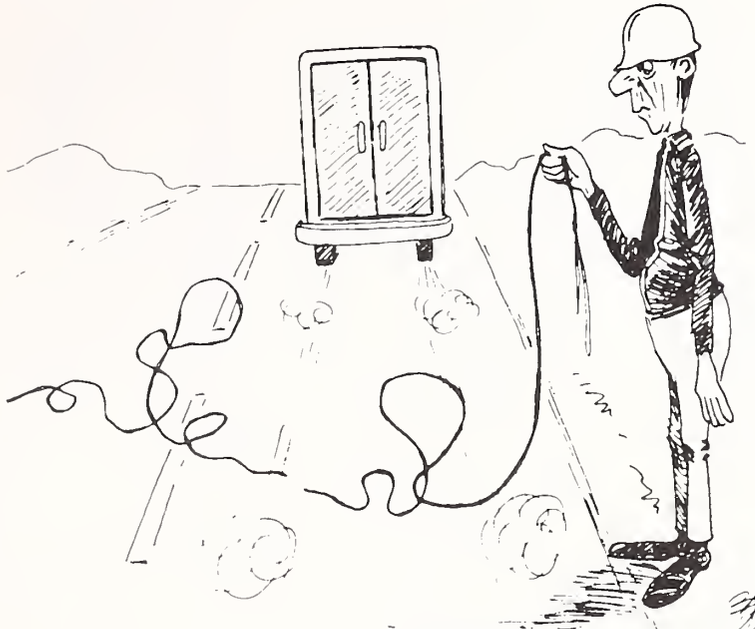
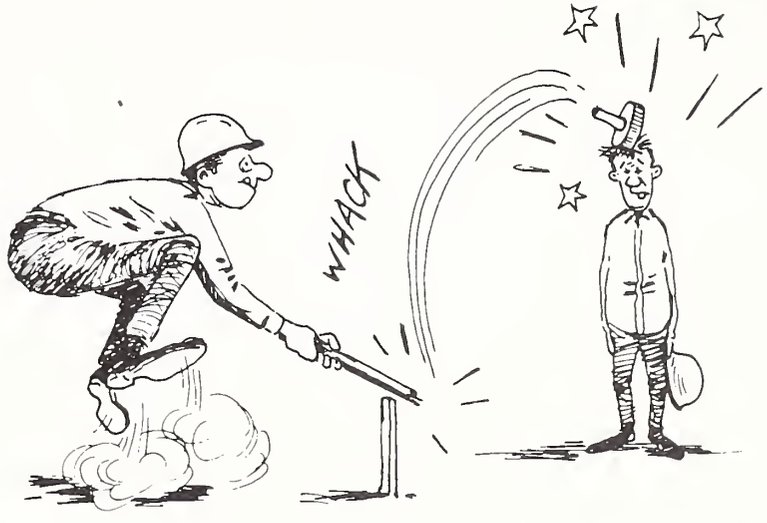
"CROSS COUNTRY 500"

SOME DONT'S IN THE USE OF SURVEY EQUIPMENT !!

"THE HUNTER"



"CHECKED 'ER OUT JUST THIS MORNING"



"MISSED AGAIN"

CONSTRUCTION MANUAL

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III-30 GENERAL

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30.01 Conventional Abbreviations

General

B.M.---------- Bench Mark

B.E.---------- Bridge End

B.R.---------- Base of Rail

C/A---------- Control of Access

C.G.---------- Curb & Gutter

Conc.---------- Concrete

Dr.---------- Drive or Drain

E.B.---------- Eastbound

Ex.---------- Existing

Ftg.---------- Footing

Fr.-Rd.---------- Frontage Road

G.R.---------- Guard Rail

Lt.---------- Left of Centerline

Med.---------- Median

D.O.H.---------- Department of Highways

N.B.---------- Northbound

N.G.---------- Natural Gas Line

O.C.---------- On Centers

O.G.---------- Old Ground

Pvm't---------- Pavement

Proj.---------- Projected and Project

P.T.W.---------- Present Traveled Way

P.L.---------- Property Line or Plate

Prw. P.---------- Power Pole

Rt.---------- Right of Centerline

R/W---------- Right-of-way

R.R.---------- Railroad or Railway

Rd.---------- Road

Rt.---------- Route

S.B.---------- Southbound

Sh.---------- Shoulder

Stkd.---------- Staked

Tel. P.---------- Telephone Pole

U.S.G.S.---------- United States Geological Survey

W.B.---------- West Bound

Curves & Surveys

B.M.---------- Bench Mark

℄---------- Centerline

C.S.---------- Curve to Spiral

D---------- Degree of Curve

D_c---------- Degree of circular curve same as spiral curvature at S.C.

$\triangle$ ---------- Delta Angle of Entire Curve

$\triangle_c$ ---------- Intersection Angle between tangents at S.C. and at C.S. or Cent. Angle of circular portion curve.

Ext.---------- External

H.I.---------- Height of Instrument

H. & T.---------- Hub and Tack

I.P.---------- Iron Pin

L_c ---------- Length of Circular Curve

L---------- Length of Vertical Curve

L_s ---------- Length of Spiral Curve

M.O.---------- Mid Ordinate

θ---------- Spiral Angle. Angle of intersection between tangent of complete curve and tangent at S.C. or C.S.

P.C.---------- Point of Curvature

P.C.C.---------- Point of Compound Curvature

P.I.---------- Point of Intersection of Main Tangents

P.O.C.---------- Point on Curve

P.O.S.T.---------- Point on Semi-Tangent

P.O.T---------- Point on Tangent

P.T.---------- Point of Tangency

R---------- Radius

Slp.Stk.---------- Slope Stake

S.C.---------- Spiral to Curve; common point of spiral and circular curve

S.T.---------- Spiral to Tangent

T---------- Tangent Length of Curve

T.S.---------- Tangent to Spiral. Common point of tangent and beginning of spiral curve.

T_s ---------- Tangent Distance P.I. to T.S. or S.T.

T.P.---------- Turning Point

V.C.---------- Vertical Curve

V.C. Corr.---------- Vertical Curve offset correction

AB---------- Abrupt

C---------- Cut

D T---------- Ditch

F---------- Fill

2:1, etc.---------- Degree of slope 2' run vs. 1' rise other slopes are expressed in a similar manner 5' run vs. 1' rise, etc.

R P---------- Reference Point, reference or reference stake

R N---------- Rounding

(10) ---------- Indicates a survey stake has been offset 10' from its correct location. Marking faces toward true location

$\frac{00}{D\ L}$ ---------- Daylight section. A projection of a ditch gradient (at a specific slope) and its intersection with the natural ground. Usually used to remove an objectionable berm adjacent to a roadway.

$\frac{00}{Sh}$ ---------- Indicates groundline at shoulder distance is at template elevation. No cut and no fill. Distance to shoulder from stake is marked below the "Sh."

O H---------- Overhang

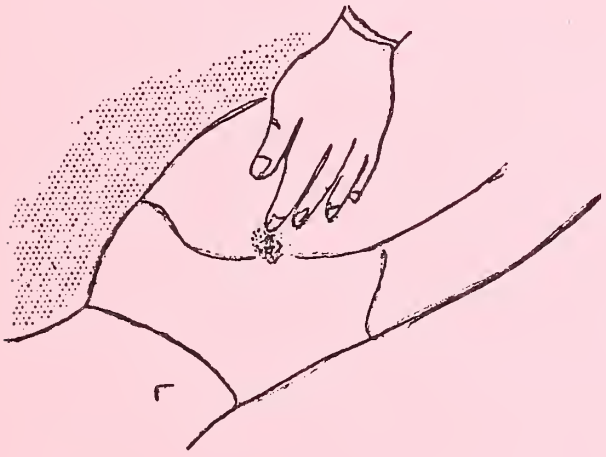
W S---------- Variable slope or warped slope

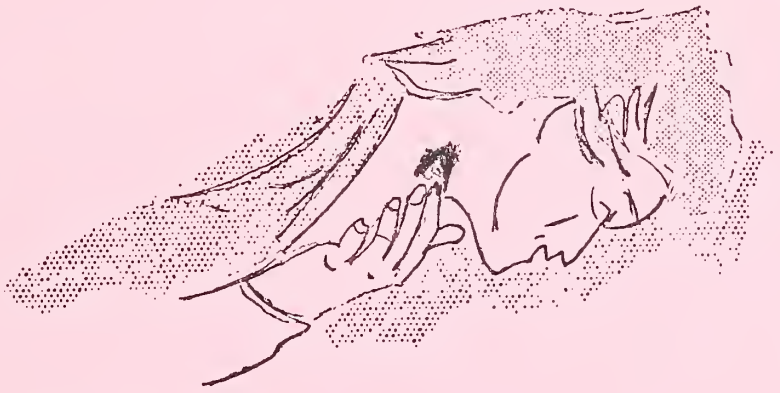
V T---------- Vertical

CARDIOPULMONARY RESUSCITATION

Suppose you are in a crowd, and someone standing near you suddenly falls to the ground and then appears completely motionless. Your ability to help that person if he has had heart stoppage (cardiac arrest) will depend on your alertness in recognizing what has happend and your ability to act smoothly without getting confused. Let us assume that someone else calls for an ambulance and keeps the bystanders in control. If you are the only one trained in CARDIO-PULMONARY RESUSCITATION, here is what you should do.

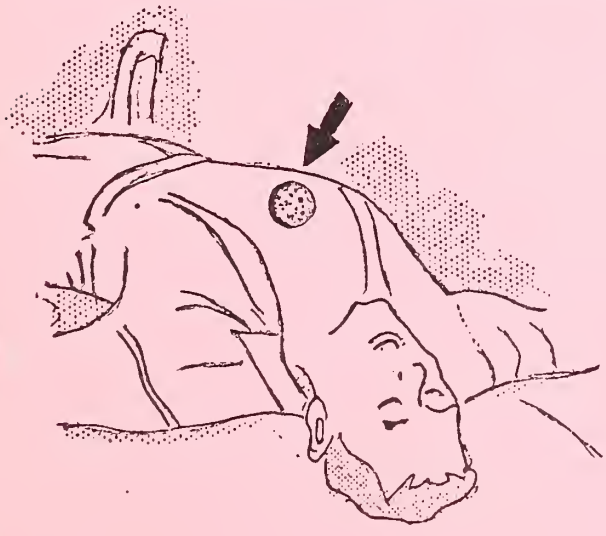
MAKE A DIAGNOSIS OF THE SITUATION





1. CHECK FOR PULSES.

Check the pulse to tell whether or not the heart is beating. Since pulses at the wrist may be very faint, you must check for pulsation of the carotid artery, located on either side of the Adam's apple in the neck. The other place to check for a faint pulse is at the femoral artery in the groin. You must learn how to find these pulses during practice so that you will not be in doubt during an emergency. Feel with the tips of the fingers and not the thumb.



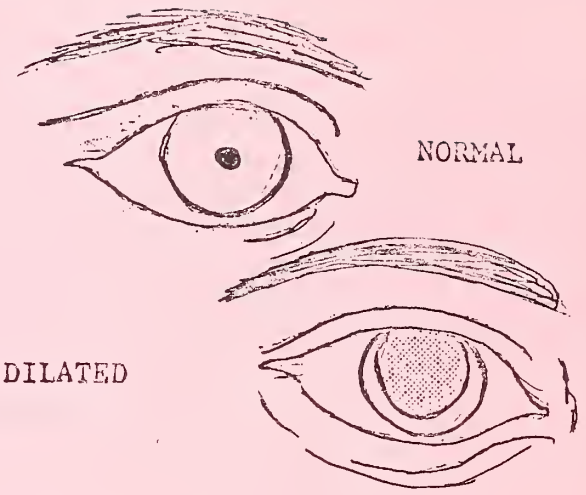
2. CHECK FOR BREATHING.

Check for breathing. The place where shallow breathing can be most easily seen is not in the chest, but in the abdomen. The patient should be examined while lying on his back, and the shirt or blouse should be opened enough to see the upper part of the abdomen clearly.

3. CHECK THE PUPILS OF THE EYES.

Look at the pupils. A person whose heart and lungs have stopped working will have widely dilated pupils. That is, the black portion inside the colored part of the eye will be very large, even when light is shining on the eye.

If the patient is without a detectable pulse or breathing, and the pupils of the eyes are dilated, the situation calls for immediate use of heart-lung resuscitation.



4. BEGIN TREATMENT

After checking to find that the air passage is not blocked in the mouth, give four full breaths of mouth-to-mouth or mouth-to-nose respiration. Make sure that the chest rises and falls with each breath.

1. Check the mouth for foreign bodies such as food, a doubled-up tonge, or false teeth.
2. With the patient flat on his back, use one hand to lift up the neck and let his head drop in extension.
3. Pinch the victim's nose closed with the other hand.
4. Take a deep breath and place your mouth over the victim's mouth with airtight contact. For a child your mouth may cover both his mouth and nose. Blow gently with a child.
5. When the victim's chest expands, stop blowing and quickly remove your mouth from his, allowing the air to escape.

Remember to keep the victim's head tilted far back. In experiments where tests of all methods of artificial respiration were made, the single most important cause of failure was not enough head tilt.

Remember that merely tilting the head back may be enough to start an unconscious person breathing again. It is also possible that the first few breaths of mouth-to-mouth respiration may result in the patient's own heart once again starting to beat. For this reason check for a pulse in the neck before starting external chest compression.

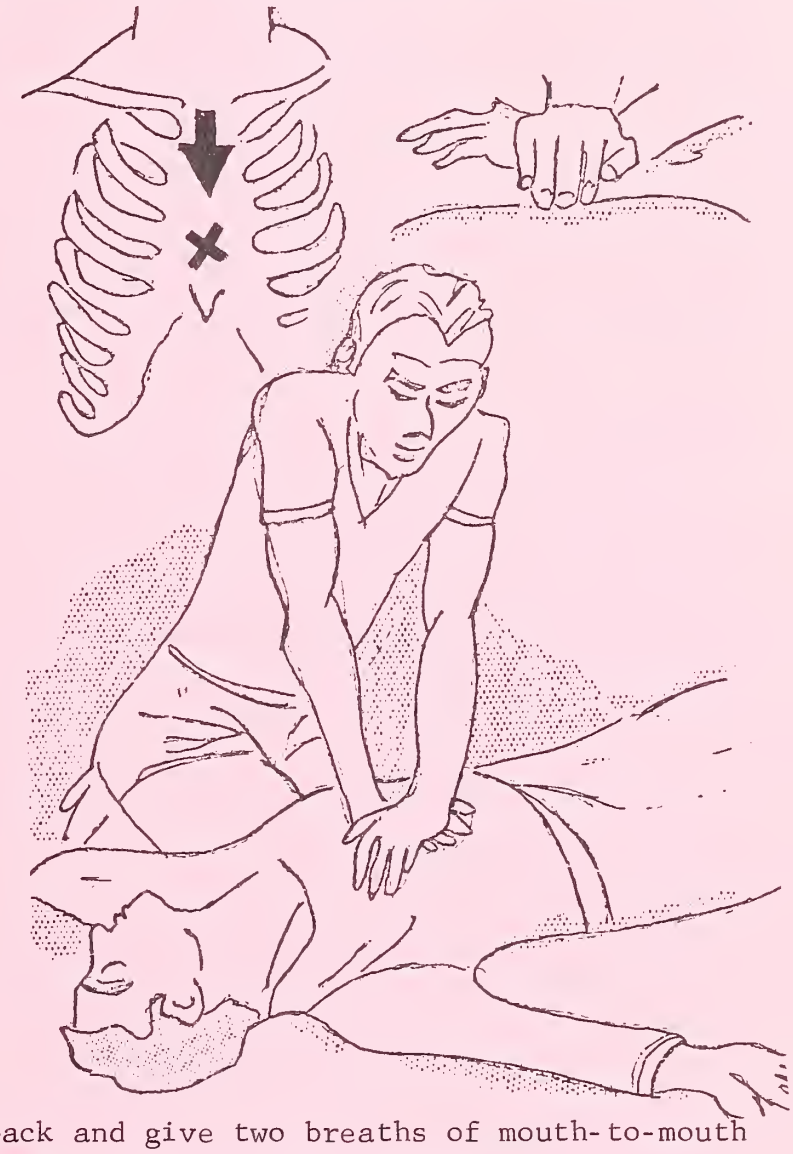
5 CHECK THE PULSE ONCE AGAIN.

6. If no pulse is present now, proceed to give closed chest cardiac compression at the rate of one per second.

1. The patient should be on his back on a firm support, preferably the floor or a table. A soft mattress in a bed or ambulance will not be hard enough unless the mattress is thin and there is a hard surface underneath. Kneel beside the patient and carefully place the heel of one hand on the lower half of the breast bone. Then put your other hand on top of the first. Be careful not to let the hand wander down to the tip of the breast bone or the sides of the chest wall. For children use only one hand. For a baby, only two fingers of one hand are needed.

2. Rock forward and let the weight of your body supply the pressure, not just your hands and arms alone. Bear down so that the breast bone is pushed down approximately one and one half to two inches with each compression. Release the pressure abruptly after each thrust, taking all pressure off the chest.

3. Continue this in rhythm, at the rate of about 60 per minute for an adult, and about 80 times per minute for a child.



7. After fifteen chest compressions, go back and give two breaths of mouth-to-mouth respiration. Return to chest compression and continue 15-and-2 cycle.

8. With every second or third cycle of chest compressions check to see whether or not the pupils have remained dilated, or have become smaller. Also, check from time to time to see if the patient's pulse has come back. This is done by momentarily checking the pulse in the neck while the chest is not being compressed. If the patient's own pulse has returned, this is a sign that his heart is beating and that you may stop doing external cardiac compression. His breathing may also come back, and you may be able to cease mouth-to-mouth respiration. If his respirations are very shallow and the color of the tongue is blue, it is all right to assist his ventilation by giving mouth-to-mouth in time with the patient's own movements with respiration.

Continue your attempts at resuscitation without stopping until the patient is functioning on hiw own, or is in the hands of a physician. Cases are now on record where a patient had to be kept on external cardiac compression and assisted respiration for as long as 55 minutes. Any pause in compression was followed by dilation of his pupils, and no heart action occurred until the patient was treated in a hospital with a defibrillator.

It is possible that with heart-lung resuscitation a patient whose heart is not beating will actually become awake. This only means that enough oxygen is being grought to his brain artificially through the efforts of the rescuers. Any pause will result in a lapse back into unconsciousness because his own heart is not operating. Again, it is possible to restore this person's heart haction with a defibrillator or other medical means and return him to normal life.

SUMMARY

1. Make a diagnosis of the situation.

   A. Check for pulses.

   B. Check for breathing.

   C. Check for the state of the pupils of the eyes.

   If the patient is without a detectable pulse or breathing, and the pupils of the eyes are dilated, the situation calls for immediate use of heart-lung resuscitation.

2. After checking to find that the air passage is not blocked in the mouth, five four full breaths of mouth-to mouth or mouth-to-nose respiration. Make sure that the chest rises and falls with each breath.

3. Check the pulse again.

   If no pulse is present now, proceed to:

4. Locate the proper spot on the chest and give 15 closed chest cardiac compressions at the rate of one per second.

5. Give two breaths of mouth-to-mouth respiration. Return to chest compression and continue the 15-and-2 cycle.

6. Halt long enough to see whether or not the patient's own pulse has returned with every second or third cycle of chest compressions. Look for breathing, and note the state of the pupils.

7. Stop chest compression if the patient's pulse returns. If breathing returns, mouth-to-mouth may be unnecessary. If the patient's heart and lungs do not begin functioning again, continue the technique while bringing the victim to the hospital until he is under the care of a physician.

Drainage

C.B.---------- Catch Basin

C.A.P.---------- Corregated Aluminum Pipe

C.S.P.---------- Corregated Steel Pipe

S.S.P.P.---------- Steel Sectional Plate Pipe

C. & G.---------- Curb and Gutter

Culv.---------- Culvert

F.L.---------- Flowline

Hdwl.---------- Headwall

D.I.---------- Drop Inlet

H.W.---------- Highwater or Headwater (infrequent use)

M.H.---------- Manhole

N.W.El.---------- Normal Water Elevation

R.C.P.---------- Reinforced Concrete Pipe

S.S.---------- Sanitary Sewer

S.---------- Storm Sewer

Vit.---------- Vitrified

Ws.---------- Water Service

W.T.---------- Water Table

30.02 General

The purpose of Chapter III is to suggest procedures, techniques, and note-keeping practices that will promote thoroughness and uniformity in setting construction stakes and performing construction measurements. The general purpose of construction surveys is to perform layout and field control for the work. This includes taking basic measurements necessary for quantity determination, then documenting these various measurements to substantiate the final payment made.

A large proportion of the construction engineering costs, nearly 30%, is consumed in the construction survey therefore, special attention is needed to promote efficiency and economy.

The Division Construction Supervisor is responsible for scheduling surveys, providing the manpower to staff the construction survey teams and quarantee that efficient practice is maintained at all times. However, the Project Manager is directly responsible for the construction survey work. He must have full knowledge of the proper methods to be employed because he is responsible for the results accomplished. The Project Manager and members of his staff are to confer with the contractor's superintendent concerning the method of staking, how stakes are to be marked and guarded, what offsets will be used, etc. The information placed on stakes, abbreviations, locations of messages, if not carefully explained to the contractors men, may result in misunderstanding or misinterpretations and delays.

The specifications provide that the contractor be held responsible for preservation of all stakes and marks. If any of the construction stakes or marks have been carelessly or willfully destroyed by the contractor the cost of replacing them will be charged against him and will be deducted from the payment for the work. Therefore, if it is necessary to replace stakes removed by the contractor's operation, separate notes should be set up stating the date replacement began, personnel and reason for replacing, so the cost of resetting may be properly documented.

A contractor's modern, high production rates make staking a very critical operation requiring detailed planning and intimate cooperation from the contractor so staking should begin as soon as is reasonably possible, and as far in advance of construction as weather and soil conditions will permit. Adequate lead time is essential to prevent delaying the contractor's operation. Staking delays that hinder construction operations will not be tolerated, assuming reasonable notice has been given to the engineer of the contractor's plans and intentions.

Project Managers, instrumentmen, rodmen, and others who are responsible for construction surveying or portions thereof should acquire the tables, handbooks, textbooks, or other data necessary for competent discharge of their engineering and surveying duties.

30.03 Safety

Each employee is responsible for his own safety but should cooperate with other crew members so that safe practices will be in effect at all times. The Project Manager or instrumentman is responsible for safe procedures and should insure that red vests or jackets, warning signs, and hard hats are properly and appropriately used. New crew members or men who seem to be accident-prone should be carefully instructed in the proper use of hand tools, axes, machetes, brush hooks, traffic control, etc.

Transits or levels must frequently be set up in the main stream of rapidly moving traffic. In such cases every reasonable precaution should be made to provide adequate advance warning to the traffic. Use flagmen when necessary. The Department of Highways does not want to lose any surveying instruments but especially, we are concerned about the safety of our personnel on the highways. Any advance warning signs set by survey personnel should be turned away from traffic when they aren't needed, i.e. during lunch breaks, and should be removed at the end of each day when their intended function has been served. Courtesy in dealing with the motoring public will help promote a safer construction surveying atmosphere.

30.04 Staking Authorization

Authorization to begin construction staking prior to contract award, can be obtained from the Construction Bureau. Frequently, the Construction Supervisor wishes to begin staking on complex projects prior to receipt of the staking authorization. On such occasions the Construction Supervisor should draft his request stating the reasons for early staking and submit the request to the Construction Bureau who will in turn obtain the proper charge numbers and submit these back to the Construction Supervisor.

30.05 Construction Survey Duties

The Project Manager is responsible for establishing lines and grades for all vertical and horizontal controls, with State forces. However, the Standard Specifications do provide for the use of contractor's personnel in giving points and lines when unusual circumstances exist. The use of contractor's personnel is done mainly on bridges, or structures. If contractor's men are used, remember that full responsibility for the accuracy of lines, slopes, grades, or other engineering work remains with the State, is under the direction of the Project Manager and must be thoroughly checked.

Construction survey teams are responsible for many different functions, some of the more important of these functions are as shown below:

1. Reproduce and reference centerline.

2. Check, set or re-establish bench levels.

3. Check plans, grades, and calculations; perform grade revisions when necessary.

4. Measure and record clearing and grubbing.

5. Stake culverts and check culvert lengths.

6. Layout and stake structures.

7. Take cross sections and set slope stakes.

8. Layout interchanges, ramps and frontage roads.

9. Set finished grade stakes for sub-grade, base surfacing and finished surfacing.

10. Preserve, perpetuate and witness planned survey monuments.

11. Take remeasure.

12. Record all pertinent survey information in a neat, legible manner. Notes should include date, weather information, survey party personnel and the signature of the crew chief.

13. Provide practical and accurate survey controls in an economical manner. It is important, almost necessary, that the majority of manpower on a survey team is skilled and precise in their duties, but it is also necessary to exchange this information, to communicate knowledge of survey skills to other less-informed men on the crew in order to promote and maintain the degree of morale necessary for efficient surveying. The rodman is truly the spark plug of the team. He can speed the team effort or slow it down. He can be a bottleneck or a highspeed precision human machine to which progress or sluggishness of the entire effort is completely dependent. A rodmans work is easier if crew members mentally check his calculations. It is very important that the various team members exchange their knowledge, help each other, and attempt to know the more important details that control the work. This interchange of knowledge and skills provides opportunity for advancement and provides the Project Manager with a team in which any one of the members can substitute for a member who is not present on any particular day.

The Project Manager has a duty to see that his crew members each have a chance to show their ability in performing such duties as chaining, rodding, "running the gun", keeping notes, and assisting in planning the surveying efforts. When each team member knows the other members work, that member is in a better position to cooperate and can better appreciate the overall needs of the work.

Staking crews are generally composed of from three to five members, but the size should be flexible to insure that other phases of the work can be adequately staffed as the need arises. Crews that are adequately staffed or even slightly understaffed are generally more efficient and experience a higher degree of morale than those which are overstaffed.

30.06 Care of Surveying Equipment

The Project Manager is charged with the full responsibility for care of all equipment assigned for his use. The complexity of his other duties require that he give frequent instruction to his men on the care of all equipment and assign various individuals the responsibility for this equipment. Many methods can be used to serve this accountability, one of which is: One man per vehicle, could be assigned to account for all equipment each day as it is taken from the vehicle, used and then returned to the vehicle. Missing equipment should be searched for by the last man using it. The instrumentman or other individual using a transit or level is in complete charge of that instrument, regarding its care, maintenance and transportation, from the start to the end of each shift. The person using an instrument is, of course, responsible for its protection and proper handling. This responsibility cannot be given to another, regardless of his rank.

The older style levels and transits are gradually being phased out and are being replaced by self-leveling levels and directional instruments or transits with enclosed working parts. The care and maintenance of the older style instruments differs from care and maintenance of the newer style instruments. The same cleaning and repair methods used in the field for one instrument cannot necessarily be adapted to newer instruments. It is, therefore, quite necessary that maintenance manuals be consulted before cleaning, repairing or making adjustments to any of the instruments. Cleaning is to be restricted to the exposed working parts, cleaning is performed with little or no removal of internal mechanisms or mechanisms that would expose internal working parts. Do not remove lenses. This allows dust to enter and may destroy the collimination or line of sight. When cleaning lenses wipe the outside of the lense with a clean, soft linen cloth or a camel's hair brush. Never use alcohol to clean lenses for this will dissolve the cement holding the lenses together.

The new style theodolites and precise transits are to be carried in their cases, not on the tripod over an individual's shoulder. The older style transits and levels may be carried over the shoulder after checking the firmness of threading on the tripod head and gently tightening the upper tangent motion. Leave the lower motion of the transit and the motion of a level unclamped. Clamp the telescope of a transit in line with its centers. Clamping should not be done so tightly that an accidential blow to the instrument will injure it. Don't climb fences with an instrument on you shoulder. Set the instrument over the fence or hand it to another person on the other side of the fence.

Instruments occasionally receive damage either accidentally or through negligence. Send damaged instruments or instruments needing repair and adjustment to the Construction Bureau, Helena, with a transmittal letter identifying the serial number. Explain the type of damage, the repair needs, and write a description of any negligence involved. If damage was caused by the contractor's employees or equipment, the report should reflect this information and the contractor should be advised so the matter may be referred to his insurance company. Repair or replacement costs are often recoverable from contractors or motorists who have struck and damaged these instruments. It will be a great help if the letter of transmittal accompanying damaged instruments has enough explanation and detail for others to become familiar with the incident. This will speed the possible recovery of repair costs from those responsible. Any individual using surveying equipment, especially instruments, must make every effort to prevent their damage. After a damaged instrument is repaired and returned to the field, inspect it and send a memo to the Construction Bureau stating that the instrument has been checked out and repairs made are O.K.. if this is the case.

Every effort will be made by the Construction Bureau to recover from State personnel, contractors or motorists, the cost to repair or replace any damaged instrument, whether the damage be through negligence or accident. This firm policy has been established in an attempt to reduce maintenance costs and reduce overall construction engineering costs, but it does not mean that every accidental damage will result in a rebate from a State employee. The Construction Bureau intends to take a reasonable attitude, but does expect responsibility and pride from field personnel in the care and use of all instruments, implements and equipment assigned to them.

30.07 Notes for Electronic Computation

Many methods are available to accomplish the surveying and staking work. It is the responsibility of the Project Manager, in charge of the construction survey and staking, to be familiar with the current calculation programs which are available and instructions pertaining thereto.

Field notes are made for electronic computation by many individuals who use different methods of forming numbers and figures. The essential requirement is that notes are legible and descriptive enough for the keypunch operators to properly reproduce the information.

Every set of cross section data that is submitted from the field to the Construction Bureau in Helena should be thoroughly and completely edited by the Project Manager, instrumentman, or

office man who is responsible for the final accuracy of the notes. Additions or changes are identified by cards placed in the appropriate position in the set of notes and further identified in colored pencil. If changes are of a nature allowing correction by Construction Bureau personnel, or others, the calculations will be completed. If the errors found cannot be corrected in Helena the notes will be returned to the field for corrections or clarification.

A. Cross Section Notes, General

All recommended practices are aimed at electronic computation of earthwork quantities while maintaining the simpliest records possible. The systems and samples conveyed by this manual have been prepared especially for adaption to the electronic computer operations. However, if all 00's and intersections of template and groundline are caught and recorded, areas can still be computed directly from the notes by hand calculator. Therefore, it is essential that all engineers follow the prescribed patterns as clearly and uniformly as possible. Cross-section notes and data are to be entered and recorded on Form CSN-01. An explanatory set of notes is shown on page 30-18B. Page 30-18C is a sample of four-lane highway. These notes concern only ordinary and usual conditions. Succeeding pages and drawings have been prepared to cover and explain some special situations which arise occasionally.

The engineer must decide when and where to take a cross-section. Bear in mind that a recorded cross-section is the basic information for determination of contractual pay quantities and that the contractor and engineer need a certain quantity of stakes, properly located. for construction of the roadway to specified dimensions. Take sufficient cross-sections, at proper locations, to truly reflect the quantities of earth to be moved.

It is common practice to take a cross-section at each 100' station; however, that is not always necessary if other sections taken nearby more truly reflect the ground situation. Sections should be taken at P.C.'s and P.T.'s or at beginning and end of spirals, at all equations, beginning and end of run-off to curves, drainage sites and other pertinent places. Sections should be taken no farther apart than fifty feet on sharp curves and in some cases the maximum should be reduced to twenty-five feet.

It is not always necessary to actually put stakes in the ground at intersections of template and ground. Suppose, for example, that cross-sections are taken every ten or fifteen feet for quantity determination but the contractor only needs stakes each fifty feet. The electronic method of earthwork computation will compute all template-ground intersections between outside catch points. However, it is absolutely necessary that all groundline breaks and template breaks be recorded and that the outside slope catch points be found and recorded. The engineer doing the staking must not deviate, from this basic requirement. See page 30-18G.

All cross-sections should extend completely beyond any work that might be done by the contractor in constructing to the requirements of the plans: groundline readings certainly should extend a reasonable distance beyond the outside grading stake.

Notes should be written with a 3H or 4H pencil, or equal. When the lead is too hard the notes are difficult to read at rapid speed and furthermore do not microfilm well. When the lead is too soft the marks tend to smear.

B. Symbols and Abbreviations

It is customary practice to use symbols and abbreviations as much as is practicable. Past practice indicates a wide variety of symbols being used. The following are to be used as standard.

RN-----Rounding	OH-----Overhang	AB-----Abrupt
VT-----Vertical	R------Reference	WS-----Warped Slope
DL-----Daylight	DT-----Ditch	AHD or
	BK-----Back	AH-----Ahead

C. Shrinkage and Swell

Practically all material used in earth work construction will either shrink or swell when taken from its original position and placed in the final position - generally roadway embankment.

Some engineers have been using what are commonly called "standard shrinkage factors". These are reflected in the following tabulation.

Shrinkage Factor	Scope of Double* End Area	*Volume Per Station Before Shrinkage	Shrinkage Factor
1.45	0 to 54	0 to 100	1.45
1.35	55 to 162	101 to 300	1.35
1.35	163 to 378	301 to 700	1.25
1.15	379 to 540	701 to 1000	1.15
1.10	541 to more	1001 to more	1.10

* To obtain the "Embankment +" volume, multiply the "Actual" embankment by the shrinkage factor appropriate for the double area or volume. Note that the volumes are "per station" meaning 100 feet. For other distances between sections the volume must be reduced to an equivalent volume per stations; e.g. two sections are 60 feet apart resulting in a volume of 387 cu. yds. To obtain a "per station" volume multiply the 387 cu. yds. by 100 and then divide by 60 giving 645 cu. yds. per station. From the table above the shrinkage factor would be 1.25.

Rock material will swell when taken from its original position. To obtain the "Embankment +" volume, multiply the "Actual" embankment by the swell factor appropriate for the percentage of rock encountered. You will note that the "Embankment +" volume will be less than the "Actual" embankment when the swell factor is applied.

Estimated Percent Rock	Swell Factor
0-10	1.00
11-25	0.95
26-50	0.90
51-75	0.80
76-90	0.75
91-100	0.70

The shrinkage and swell factors in the tabulation are general or approximate only. Such a tabulation cannot, by any stretch of the imagination, conform to all types of soils and conditions encountered in roadway construction. Some engineers will increase or decrease the factors a certain percentage as their judgment dictates. Judicious selection of such changes, based on experience, can produce very good results in constructing a roadway. The engineer might decide that the factors in the table should be increased 10%, or 20%, due to the type of soils and the location of the embankment.

Other engineers will decide that between Station 0+00 and Station 35+50 the material will shrink 10%, that between Station 35+50 and Station 73+00 it will shrink 20%; that between Station 73+00 and 115+60 it will swell 5%; etc. These shrinkage factors would be applied to all quantities, regardless of size. These determinations would be based on experience with the various types of soils and conditions being encountered.

When earthwork quantities are being determined in the headquarters office by electronic computer, the engineer's recommendations concerning shrinkage and swell must accompany the staking notes.

D. Common Errors

1. General

The compilation of staking notes and their application to the electronic computer has been exceptionally good but, as always happens in a large program involving a great many personnel, a few errors and misunderstandings just naturally occur. This Article deals with those that have occured frequently.

2. + and - Rods

It has been and will continue to be, common practice to assume that, when there is no sign in front of a rod reading, the rod reading is a minus (-); in other words, the reading under consideration is below the height of instrument. It also is common practice to write a plus (+) sign in front of a rod reading denoting ground or template higher than H.I. There have been a few occasions where there were a series of (+) readings and in between were one or two without sign:

Thus $\frac{+5.6}{19}$ $\frac{+4.1}{25}$ $\frac{+3.6}{28}$ $\frac{+2.8}{30}$ $\frac{1.2}{33}$ $\frac{1.4}{35}$ $\frac{+2.3}{38}$ $\frac{+3.2}{41}$ etc.

The persons using the notes don't know whether the readings at 33 and 35 are actually (-) readings or whether the notekeeper forgot the (+) sign. It is suggested that, if they really are (-) readings, they be written thus $\frac{-1.2}{33}$ $\frac{-1.4}{35}$ in such a case.

3. Distance Out Of Sequence

It occasionally happens that a distance reading is out of proper sequence: thus 00, 10, 15, 25, 20, 31, 36.

Are the readings at 25 and 20 reversed? Should the 20 be 28 or 30? Is there a cave or overhang? If the readings are true, explain. Be sure to edit the notes for such occurrences.

4. Catch Point Not Defined

Occasionally the catch points, particularly the outside fill or cut, are not clearly defined or readily discernible. It is imperative that all note records use a standard practice in the case of outside catches. See page 30-18A, Paragraph "R" and page 30-18 B. Leave at least one blank space each side of the outside catch; enter the amount of cut or fill above the rod reading.

5. Excavation Without Centerline

Occasionally a borrow area is cross-sectioned without a centerline or baseline. This usually happens as an extension of roadway sections off the roadway centerline. It is essential that every set of cross-sections have a centerline or baseline. See page 30-18 D.

6. Wrong H.I.

Sometimes the notekeeper will, in transposing the H.I. to the next page, get the number mixed, usually the first two digits e.g., 3152.69 carried forward and written as 4152.69. When the cards are punched using an erroneous H.I. some incorrect answers are certain to result. This should be carefully watched. Sometimes this goes right on by a Bench Mark without correction.

7. H.I. in Wrong Column

Occasionally a recorder will write the H.I., when starting a new page, in some column other than the H.I. column. This causes trouble in card punching because all rod readings are reduced to elevation. Erroneous H.I. produce erroneous elevations and end areas.

8. Decimal Points

Now and then a recorder will forget to enter a decimal point in a rod reading or distance, or enter a decimal point where there should be none. This should be watched carefully. They cause delay and wrong answers.

E. Road Approaches, Dikes, etc.

Most road approaches and small dikes will be constructed by use of only a few guide and reference stakes. There may be occasions, however, when it will be necessary to run out and stake the approach or dike, similar to a roadway. When this occurs, treat it just like a roadway, using centerline, shoulders, slope stakes, etc. The quantities can be included in the roadway mass if desired.

F. Bluetops

The operation of construction staking is not complete until the roadway, ditches and other attendant facilities have been completed to designed section. Finishing stakes, popularly called "bluetops", shall be set to line and grade as the roadway grading progresses from rough toward finish. The top should never vary more than 0.05 ft. from true elevation. The roadway centerline must be run in by transit and chain and the grades established by level. A line of bluetops is essential for centerline and each shoulder. These three lines will suffice for narrower roadways. There will be many occasions, particularly on the Interstate System with very wide sections, where five lines of bluetops will be necessary---centerline, each shoulder, and about halfway between centerline and shoulder.

There will be occasions when ditch or channel flow lines should be bluetopped. This is especially essential when runoff grades are very nearly flat.

All bluetops must be set true to line and grade. It is especially important to have shoulder bluetops true to line to attain a good appearing shoulder line. It is essential that bluetops be set to true grade line, and the grade work finished accordingly, so that a smooth riding surface will be the result.

G. Corrections to Notes

There will be occasions when the cross-section notes must be amended or supplemented or otherwise revised after Data

Processing Bureau has computed the quantities. Data Processing tabulates all of the cross-section data, both template and groundline, on cards and saves them for future use. Remeasure is one such use.

If the engineer finds it necessary to change the groundline record, such changes, generally, should be done with red pencil so that they are easy to find. If the changes are reflected on completely new sheets, like borrow widening or such cases, the notes need not be in red, but should be clearly marked and noted that the change is to be considered when computing remeasure quantities.

When remeasure notes are sent to the Construction Bureau for computation of quantities, it may or may not be necessary to also send the groundline notes. If the groundline notes have been submitted once for original computations, and no changes or additions were made subsequently, then they need not be re-sent to Helena. If only a few changes were made, comparatively speaking, it might suffice to send in only the sheets or pages which were modified. The field engineer should exercise his best judgment in making this determination. The answers received back from the Data Processing Bureau will conform to the basic information submitted to it.

H. Unusual Situations

Unusual problems and situations occur, occasionally, which are not covered and discussed in this manual. It is impossible to anticipate everything and these situations may occur only once in a "coon's age".

When such a situation or problem is encountered, and quantities are to be determined by the electronic computer, the field engineer should immediately contact the Construction Bureau in Helena and reach an agreement as to procedure and method to follow. There have been cases where the field engineer went to a lot of work to prepare notes for subsequent computations when he fully wasted his time and that of personnel in headquarters, mostly because he was not fully cognizant of what could or could not be done by the existing computer program. Several of the problems had an easy solution when attacked by a person having full knowledge.

So---don't hesitate to try the Construction Bureau if the Manual does not provide the solution.

I. Data Transmittal

When staking and remeasure notes are submitted to Helena for computation of areas, volumes, etc., the package must be addressed to:

Construction Bureau
Department of Highways
Helena, Montana 59601

The package must be identified on the outside, near lower left corner, by project number and types of notes.

e.g., F 192(7)
Cross Section Notes

It is also necessary that a memorandum of transmittal be submitted in duplicate, separately from the notes. The memorandum shall contain such information as project number, type of notes (construction, remeasure, etc.) stating coverage, and any other pertinent data. The Construction Bureau will transmit the data to the Data Processing Bureau. The requested information will be sent back to the field engineer as soon as processing has been completed. All contact with the Data Processing Bureau will be coordinated through the Construction Bureau.

Pages 30-18"O" thru 30-18"S" show samples of coding sheets used to submit various forms of data to be key punched for electronic processing.

EXPLANATORY NOTES FOR PLATE NO. VII-05-01

THESE NOTES EXPLAIN THE ENCIRCLED LETTERS, SHOWN IN VARIOUS PLACES ON THE EXEMPLARY CROSS-SECTION NOTES ON PLATE VII-05-01.

-A- ALL ROD READINGS MUST BE WRITTEN TO THE NEAREST 0.1 (TENTH) FOOT, EVEN WHEN THE READING IS AN EXACT FOOT, SUCH AS 9.0. DECIMAL POINTS MUST BE CLEARLY SHOWN. THE ONLY SIGN TO PRECEDE A ROD READING, GENERALLY, IS A "+" SIGN: OTHER READINGS WILL BE UNDERSTOOD TO BE (-) MINUS. (SEE NOTE -T-.)

-B- RECORD DISTANCES TO THE NEAREST FOOT (25) FOR MOST CONDITIONS. THERE WILL BE CASES WHEN IT WILL BE NECESSARY TO RECORD TO THE NEAREST 0.1 (TENTH) FOOT (31.8), SUCH AS SLOPE STAKES, CURBS, IMMOVABLE STRUCTURES, ETC. USE DECIMAL POINTS WHEN SHOWING DISTANCES LESS THAN ONE FOOT (0.7).

-C- THE H.I. (HEIGHT-OF-INSTRUMENT) MUST BE ENTERED IN THIS COLUMN AT ALL TIMES. IT NEED NOT ALWAYS BE AT THE TOP OF THE PAGE. IF A TURN IS RECORDED NEAR THE MIDDLE OF THE PAGE, THE H.I. WOULD OCCUR THERE, BUT IN THIS COLUMN. THE PUNCH CARD OPERATORS COULD MISS IT QUITE EASILY IF IT IS CARRIED ELSEWHERE. WHEN H.I. IS CARRIED FORWARD FROM ONE PAGE TO THE NEXT, ENTER IT AS SHOWN AT C. WHEN A TURN IS MADE, OR B.M. CHECKED INTO, ENTER AS SHOWN AT BOTTOM OF THE COLUMN. THE RECORDER ALWAYS MUST BE CAREFUL TO RECORD H.I. IN SIX FIGURES. A COMMON ERROR IS TO INCORRECTLY COPY THE FIRST TWO FIGURES AND THUS BE OFF A HUNDRED FEET OR MORE. THE OTHER HEADINGS (+, -, ELEV.) APPEAR TO BE SELF-EXPLANATORY.

-D- EACH DAYS WORK SHOULD SHOW THE NAMES OF THE PERSONNEL DOING THE STAKING AND THE TYPE OF WORK EACH PERSON DOES -- SUCH AS INSTRUMENT, ROD, CHAIN, ETC. IF A CHANGE IN PERSONNEL IS MADE DURING THE DAY, IT MIGHT BE DESIRABLE TO MAKE A NOTATION TO THAT EFFECT.

-E- IT IS RECOMMENDED THAT THE "REMARKS" SPACE BE USED AS OCCASION DICTATES. WEATHER CONDITIONS AND TEMPERATURE SHOULD BE NOTED EACH DAY; MORE THAN ONCE, IF NOTED CHANGES OCCUR.

-F- THE PROJECT NUMBER OR IDENTIFICATION SHOULD BE SHOWN FREQUENTLY. THE ENGINEER WOULD NOT BE WRONG IF HE ENTERED IT ON EVERY PAGE.

-G- THE ENGINEER MAY DEVISE HIS OWN SYSTEM OF PAGE NUMBERING. POSITIVE IDENTIFICATION IN PROPER SEQUENCE IS IMPORTANT.

-H- THE DATE SHOULD BE ENTERED, AT THE LEAST, AT THE BEGINNING OF EACH DAYS WORK.

-I- BENCH MARKS AND TURNING POINTS (B.M. & T.P.) SHOULD BE RECORDED AS SHOWN. THE METHOD SHOWN IS USED BY MOST ENGINEERS. A COMPLETE DESCRIPTION MUST BE PROVIDED AS TO TYPE AND LOCATION OF B.M. T.P.'S ARE NOT SO IMPORTANT; MOST ARE TEMPORARY FOR THE ONE TURN; SOMETIMES THEY MAY BE REFERRED TO SEVERAL TIMES. THE TYPE OF USE AND REUSE SHOULD BE CONSIDERED.

-J- THIS COLUMN SHOULD BE USED, AT ALL TIMES, FOR RECORDING STATION NUMBER AND STATION PLUS NUMBER. THIS IS, OF COURSE, QUITE IN KEEPING WITH CUSTOM. THE FIRST ENTRY IN THIS COLUMN, ON ANY PAGE, SHOULD BE COMPLETE AS TO STATION AND PLUS -- E.G. -- WRITE "136+17" -- NOT JUST "+17".

-K- THE FIGURE "43.80" IS PROFILE GRADE REDUCED TO SUBGRADE ELEVATION BY THE SURFACING THICKNESS. SOME ENGINEERS WOULD PREFER TO WRITE "2143.80". THIS INFORMATION SHOULD BE INSERTED IN THIS SPACE AT ALL TIMES.

-L- A FOUR-LINE SPACE, SUCH AS 'L' AND 'M' WILL BE CALLED "QUAD-SPACE" IN FURTHER DISCUSSIONS. THE TEMPLATE RODS (GRADE RODS) AND OISTANCES ALWAYS SHOULD BE WRITTEN INTO THE SAME QUAD-SPACE AS THE STATION AND GRADE. THE TEMPLATE READINGS SHOULD SHOW ALL OF THE BREAKS IN THE COMPLETED ROADWAY SECTION, EXCEPTING THE OUTSIDE CATCH POINTS WHERE TEMPLATE INTERSECTS GROUND.

-M- THE FIRST QUAD-SPACE BELOW THE TEMPLATE NOTATIONS IS TO BE USED FOR GROUNDLINE READINGS. IT ALSO WILL CARRY SLOPE STAKE DATA AND OTHER PERTINENT INFORMATION, SUCH AS ILLUSTRATED. THE LOWER OF THE FOUR SPACES OF THE QUAD-SPACE, WHICH HAS NO VERTICAL LINES, IS TO BE USED FOR NOTATIONS SUCH AS RATE OF SLOPE (5:1 OR 5), REFERENCE (R), END CUT, ETC., ETC. THIS APPLIES TO BOTH TEMPLATE AND GROUND LINE READINGS. IT IS A FREQUENT OCCURRENCE FOR SO MANY GROUND READINGS TO BE RECORDED THAT ALL CANNOT BE ENTERED ON ONE LINE. IN SUCH CASE, PROCEED AS ILLUSTRATED ON THE RIGHT SIDE FOR STATION 15+45. ON THE RIGHT SIDE, THE FIRST LINE SHOULD READ FROM LEFT TO RIGHT, THE SECOND RIGHT TO LEFT, THE THIRD LEFT TO RIGHT, ETC. THE LEFT SIDE OF CENTERLINE WOULD BE THE OPPOSITE.

-N- ALWAYS LEAVE AT LEAST ONE QUAD-SPACE BETWEEN THE LAST QUAD-SPACE USED BY A CROSS-SECTION AND THE FIRST QUAD-SPACE USED BY THE NEXT CROSS-SECTION. DO NOT CROWD THE NOTES.

-O- REFERENCE STAKE OR REFERENCE POINT ENTRIES SHOULD BE SHOWN AS ON PLATE VII-05-01. THERE WILL BE OCCASIONS, SUCH AS A CHANNEL CHANGE NEAR THE OUTSIDE OF THE RIGHT-OF-WAY, WHEN THE ENGINEER WILL WANT THE REFERENCE POINT BETWEEN SUCH A CHANNEL AND THE ROADWAY. HE CAN WRITE "R" UNDER WHICHEVER POINT HE CHOOSES AND RECORD ON OUT TO THE DECIDED LIMIT.

-P- THE ENGINEER FREQUENTLY WILL DESIRE TO ENTER SUCH NOTES AS "END DITCH LEFT", "BEGIN CUT RIGHT", ETC., ETC. SUCH NOTES CAN BE ENTERED AS SHOWN AT STA. 15+80 LEFT SIDE. (REQUIRES A ENTIRE SECTION FOR CALCULATION)

-Q- NOTE THAT AT STA. 15+45 THE 00/11.3 WAS FOUND AND RECORDED. THERE ACTUALLY ARE THREE "00'S" AT STA. 15+80 BETWEEN CENTERLINE AND 20 FT. RIGHT; THEY WERE NOT CAUGHT. THE ELECTRONIC COMPUTER WILL INTERPOLATE THEM AUTOMATICALLY. SEE PLATE VII-05-06.

-R- SOME ENGINEERS DESIRE TO INDICATE THE RATE OF FILL SLOPE OR CUT SLOPE STAKE READINGS. SEE STA. 15+00, READINGS AT 22.0 AND 45.4. THE FILL SLOPE OR IN-SLOPE IS 5:1, RECORDED AS 5; THE BACK SLOPE IS 2:1 AND RECORDED AS 2; A DAYLITE SITUATION WOULD USE "DL" BELOW THE READING (00/5.4/35.7/DL). THE RECORDER MAY INDICATE THE RATE OF SLOPE BY EITHER "5" OR "5:1". SUCH ENTRIES ARE NOT NECESSARY TO ELECTRONIC COMPUTATION.

-S- VERTICAL FACES OR SITUATIONS CAN BE ENTERED IN THE NOTES AT THE ACTUAL DISTANCE WITHOUT HAVING TO ADD OR SUBTRACT ANY AMOUNT. THREE, BUT NO MORE, READINGS AT THE SAME DISTANCE CAN BE RECORDED IN EITHER GROUNDLINE OR TEMPLATE OR BOTH.

-T- WHEN THE ENGINEER HAS A SERIES OF PLUS RODS AND IN BETWEEN HAS ONE OR TWO MINUS RODS. IT WOULD BE VERY HELPFUL IF THE MINUS SIGN WERE ENTERED IN FRONT OF THE ROD READING, AS SHOWN AT STA. 15+80 RIGHT. SUCH AN ENTRY CLEARS UP ANY DOUBT THAT MIGHT OCCUR TO THE READER.

-U- AT LEAST ONE BLANK SPACE SHOULD BE LEFT IN THE NOTES ON EACH SIDE OF THE OUTSIDE CATCH SHOT, AS SHOWN FOR STA. 15+45. THIS MAKES IT MUCH EASIER FOR PUNCH CARD OPERATORS TO FIND THE FIRST AND LAST TEMPLATE READINGS.

DEPARTMENT OF HIGHWAYS

CONSTRUCTION MANUAL

PLATE NO. VII - 05 - 01

DATE APRIL 30, 1973

"SAMPLE CROSS-SECTION NOTES"

PERSONNEL JONES (A) SMITH (D) MACK | TRENT | DAVIS

REMARKS CLEAR & WARM (E) ± 75°

PAGE 6 (G)

DATE 6-15-60

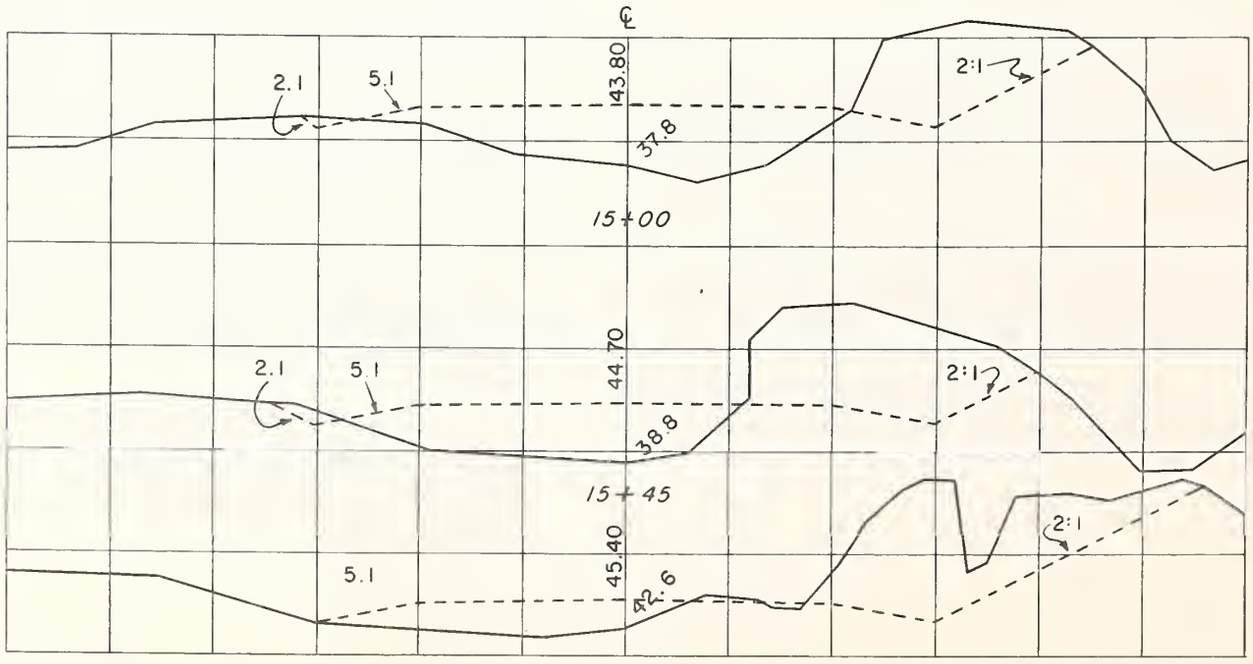
PROJECT NO. S-99 (4) (F) (H)

(J) STATION	℄	H.I. 2149.88 (C)	-	ELEV.
15+00 43.80 (K)		(L)		8.5 30 — 6.5 20
	(M) F4.5 11.0 60 R (O) — 10.7 53 — 8.3 46 — C0.9 7.6 31.8 (B) 2 — (A) F1.3 7.8 26.5 5 — 8.1 20 — 11.1 11 OR 5:1			
(N)	OR 2:1 OR NOT DENOTED AT ALL.			
15+45 44.70		(U)		7.6 30 — 5.6 20
	F0.3 5.3 60 R — 4.6 47 — C2.2 5.4 34.4 2 — 5.5 32 — F1.5 7.1 27.5 5 — 9.9 19			
(N)				
15+80 45.40				6.9 30 — 4.9 20
	C2.7 2.2 60 R (P) END D.T. — 2.7 45 LT. — F2.0 6.9 30.0 5 — 8.1 8			
BM (I)		+2.04	2147.84	
	+5.26 — 2153.10			

FORM NO. CSN-01

℄													
	6.1	6.5 20	8.5 30										
	F6.0 12.1	13.7 7	11.9 14	F0.4 6.9 22.0 5 (R)	00 25	+1.8 33	+0.6 43	C7.7 0.8 45.4 2 (R)		4.9 50	10.5 53	13.1 57	
				OR 5:1 OR NO ENTRY AT ALL								F5.7 12.2 60 (O) R	
	5.2	5.6 20	7.6 30										
	F5.9 11.1	10.1 6	00 5.4 11.3 (Q)	4.9 12	+1.1 12	+4.1 15	+4.4 22	+0.1 36	C5.0 2.6 40.0 2 (U)		4.9 43	10.3 48	
				(S)					F1.1 8.7 60 R		12.3 55	12.4 50	
	4.5	4.9 20	6.9 30										
	F2.8 7.3	4.0 8	4.4 13	5.2 15 (Q)	5.3 17	0.8 21	+2.8 23	+6.1 27	+7.1 29	+7.1 32 (T)	-2.2 33	-1.1 35	+5.3 38
						C8.2 +3.3 60		C13.0 +6.1 56.0		+6.8 54	+4.8 47	+5.6 43	
	BM 2147.85 IRON PIN 2" OUT OF GROUND, 60' LT. OF ℄ STA. 15+80												

FORM NO. CSN-01



THESE SECTIONS PLOTTED FOR ILLUSTRATION ONLY

Rev. 5-1-73

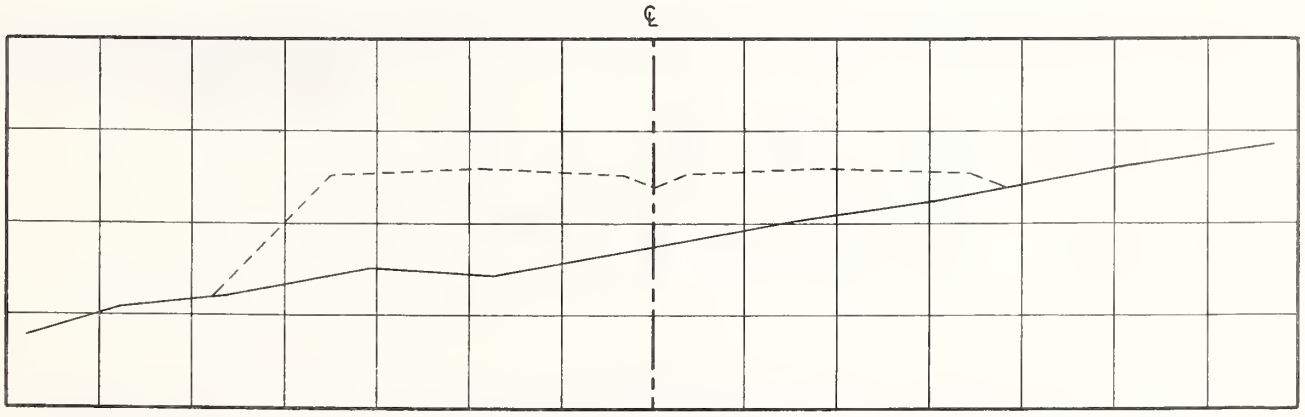
DEPARTMENT OF HIGHWAYS

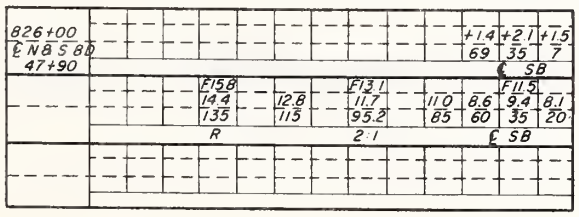
CONSTRUCTION MANUAL

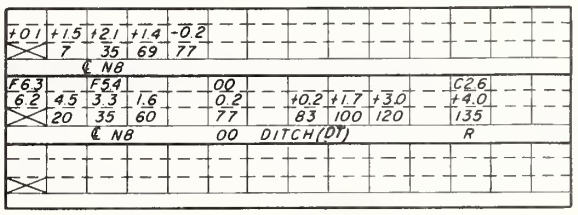
PLATE NO. VII-05-02

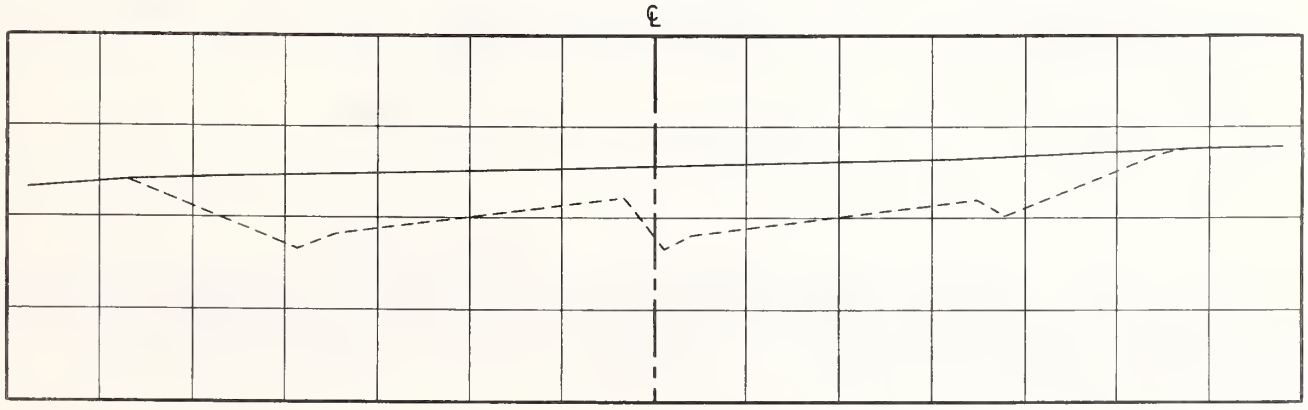
DATE APRIL 30, 1973

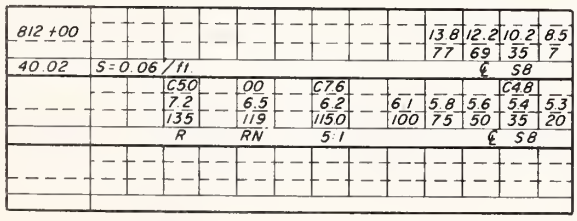
"FOUR-LANE ROADWAY"

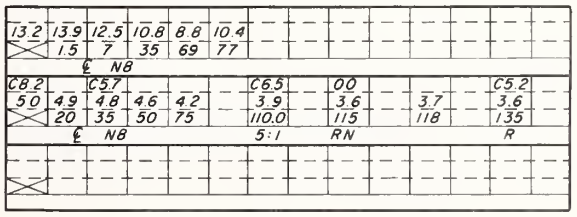












THE TWO SECTIONS ILLUSTRATED ON THIS PLATE SHOW ONE WAY OF STAKING A FOUR-LANE HIGHWAY. THE UPPER SKETCH SHOWS A SECTION ON TANGENT. THE LOWER A SECTION ON A CURVE. THERE ARE SEVERAL METHODS THAT CAN BE AND ARE USED. THIS ONE SEEMS TO WORK OUT QUITE WELL. THESE SKETCHES SHOW HOW THE NOTES SHOULD BE KEPT FOR ELECTRONIC COMPUTATIONS. THEY WILL WORK EQUALLY WELL FOR HAND CALCULATOR COMPUTATION IF ALL 00'S, AS WELL AS ALL SLOPE STAKES, ARE FOUND AND RECORDED.

THE IMPORTANT FEATURE IS THAT ALL ENGINEERS ADOPT AND USE A UNIFORM SYSTEM OF RECORDING NOTES, SUCH AS SET OUT IN THIS SECTION OF THE MANUAL.

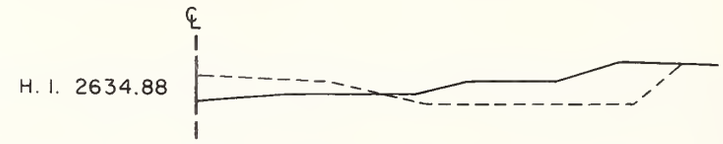
IF AND WHEN PARALLEL DITCHES, DIKES, ROADWAYS, ETC., ARE TO BE STAKED ALONG WITH AND AT THE SAME TIME AS THE MAIN ROADWAYS, THE TEMPLATE NOTES, AS WELL AS THE GROUND-LINE NOTES, CAN BE EXTENDED TO INCLUDE THOSE FACILITIES. PLATE VII-05-03 PROVIDES ONE METHOD OF HOW TO PROCEED.

DEPARTMENT OF HIGHWAYS — CONSTRUCTION MANUAL

PLATE NO. VII-05-03

DATE APRIL 30, 1973

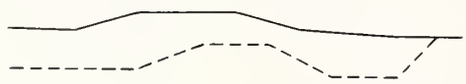
CASE 1. "BORROW WIDENING"



Template	4.0/00		10.0/20		13.3/35			13.3/68	
Ground	12.7/00	12.0/13	F1.8 11.8/29.0	11.8/32	10.0/42	10.0/55	6.6/65	C6.3 7.0/74.3	7.5/80

CASE 1. THIS EXAMPLE SHOWS A NORMAL FLAT BOTTOM DITCH SECTION AND THE APPROVED METHOD OF RECORDING GROUND AND TEMPLATE NOTES.

CASE 2.



Template	8.9/100	5.5/110	5.5/120	10.0/130	10.0/140		
Ground	3.3/90	0.5/100	0.5/115	3.0/125	3.8/140	C6.2 3.8/146.2	3.8/150

CASE 2. THE ENGINEER FOUND IT NECESSARY TO EXTEND THE CROSS-SECTION NOTES TO WIDEN THE BORROW, AND TO BUILD A BERM AND CHANNEL AFTER STAKING THE SECTION IN CASE 1. THE EXTENSIONS CAN BE STAKED USING THE SAME OR A DIFFERENT H.I., THEN CONTINUING ON TO THE RIGHT AS ILLUSTRATED UNDER CASE 2. SEPARATE NOTES ARE KEPT FOR THE EXTENSIONS BUT THE ENGINEER MUST MAKE THE EXTENSIONS STATION FOR STATION WITH THE ORIGINAL NOTES SO THE QUANTITIES INVOLVED WILL BE CALCULATED AND INCLUDED WITH THE ORIGINAL STAKED QUANTITIES. THE ORIGINAL NOTES MUST BE AMENDED BY DRAWING A RED LINE THROUGH THE C 6.3.

CASE 3.

(A) 10.0/00	Template	9.5/80	9.6/86.2	16.4/93						16.4/140		
(A) 10.0/00	Ground	9.5/80	C6.8 9.6/86.2	9.7/90	6.9/100	6.9/115	9.4/125	10.2/140	C6.2 10.2/146.2	10.2/150		

CASE 3. HERE THE ENGINEER DOES NOT WISH TO EXTEND THE ORIGINAL CROSS-SECTIONS, BUT RATHER TIE BACK TO CENTERLINE OR BASELINE BY INSERTING "FAKE" READINGS AT "A" AND REPEATING THE GROUNDLINE READINGS AT 80 AND 86.2 IN THE TEMPLATE READINGS SUCH THAT NO AREA CALCULATIONS WILL BE MADE BETWEEN 00 AND 86.2. THE VOLUMES CALCULATED IN CASE 3 WILL BE SEPARATE FROM THOSE ORIGINALLY STAKED.

THE CROSS-SECTIONS MUST BE TAKEN AT THE SAME SECTIONS AS ON CENTERLINE, IF TO BE MERGED WITH CENTERLINE QUANTITIES.

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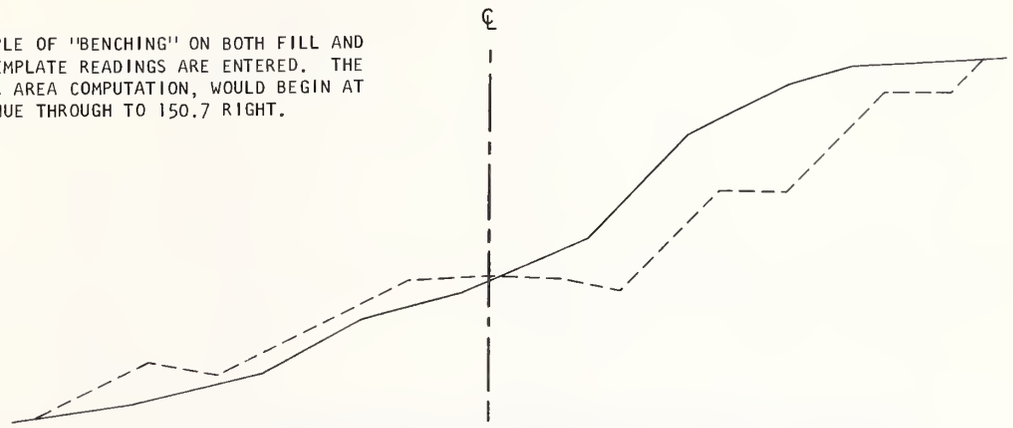
PLATE NO. VII-05-04

DATE APRIL 30, 1973

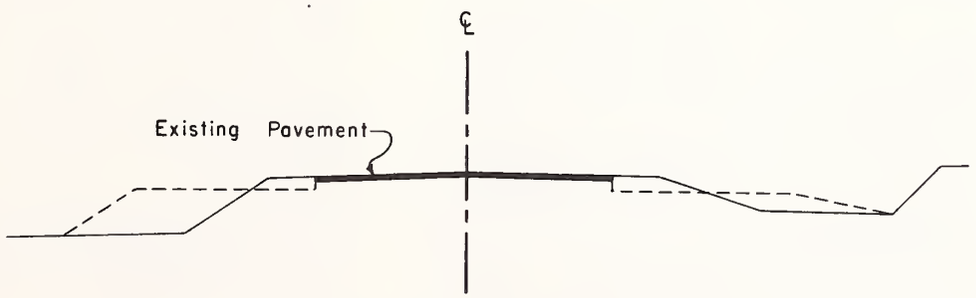
"BENCHING"

THIS IS AN EXAMPLE OF "BENCHING" ON BOTH FILL AND CUT. NOTE HOW THE TEMPLATE READINGS ARE ENTERED. THE TEMPLATE SECTION, FOR AREA COMPUTATION, WOULD BEGIN AT 137.8 LEFT AND CONTINUE THROUGH TO 150.7 RIGHT.



Template				67.6 / 105	70.6 / 85	40.6 / 25	40.0 / X	40.4 / 20	44.4 / 40	14.4 / 70	14.9 / 90	+15.1 / 120	+14.6 / 140	
Ground	F 45.0 / 145 / R	F16.4 / 84.0 / 137.8	80.0 / 110	90.0 / 70	54.2 / 40	45.5 / 9	41.6 / X	00 / 40.1 / 5.0	28.2 / 30	+2.9 / 61	+17.4 / 90	+23.3 / 110	+25.3 / 150.7	C10.7 / C66.0 / +26.6 / 155 / R

"PAVEMENT WIDENING"



Template					3.5 / 9	2.8 / 9	2.4 / X	2.7 / 9	3.5 / 9					
Ground	6.6 / 28 / R		6.3 / 17	00 / 3.6 / 13.2 / DL	2.9 / 12	2.8 / 9	2.4 / X	2.7 / 9	2.8 / 12	00 / 3.6 / 14.7 / DL	4.8 / 18	4.9 / 26	2.0 / 29	2.0 / 30

THIS ILLUSTRATES WHAT IS PRIMARILY A SURFACING PROJECT OVER WIDENING OF EXISTING PAVEMENT. THE TEMPLATE AND GROUNDLINE READINGS WOULD BE ABOUT AS SHOWN. THE ONLY QUANTITIES TO BE DETERMINED ARE EXCAVATION. THE SHOULDERS WILL BE OBTAINED BY BLUE-TOPS AND THE SLOPES BY MACHINERY

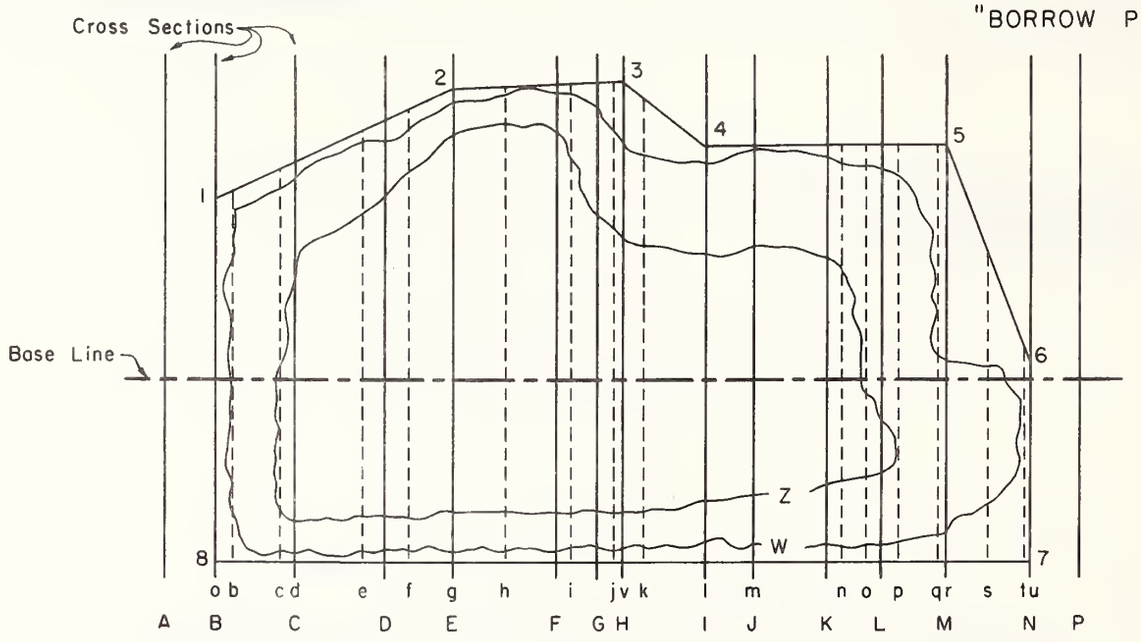
DEPARTMENT OF HIGHWAYS

CONSTRUCTION MANUAL

PLATE NO. VII - 05 - 05

DATE APRIL 30, 1973

"BORROW PITS"



THE MEASUREMENT AND COMPUTATION OF QUANTITIES INVOLVED IN BORROW PITS OR BORROW AREAS CAN BE HANDLED IN VARIOUS MANNERS. THE SAME PROCEDURES CAN BE APPLIED TO STOCKPILES. ONE LINE COMMON TO ALL METHODS IS BASELINE OR CENTERLINE. WHETHER SUCH A LINE TRAVERSES THE APPROXIMATE CENTER OF THE AREA OR IS OFF TO ONE SIDE IS OF MINOR CONSEQUENCE. MOST ENGINEERS PREFER A CENTERLINE OR BASELINE NEAR CENTER. TWO METHODS WILL BE DISCUSSED ON THIS PLATE.

(1) THE ENGINEER ESTIMATES THE BOUNDS OF THE POSSIBLE BORROW AREA, RUNS OUT A CENTERLINE OR BASELINE AS SHOWN ON THE SKETCH, AND DETERMINES THAT CROSS-SECTIONS WILL BE REQUIRED AT VARIOUS PLUSSES DENOTED A, B, C, ETC., N AND P, EACH OF THE LENGTH SHOWN. WHEN THE EXCAVATION IS COMPLETE, HE RETURNS AND RECROSS-SECTIONS ON THE SAME PLUSSES OR LINES AND PROBABLY FINDS IT NECESSARY TO ADD A FEW SECTIONS. HE PROBABLY WOULD VOID THE SECTIONS AT A AND P. HE WOULD, IN THIS CASE, NEED ADDITIONAL SECTIONS AT b, c, e, f, h, i, j, k, n, o, p, q, s and t. HE WOULD HAVE TO INTERPOLATE A GROUNDLINE FOR EACH OF THESE. HE WOULD THEN FIGURE THE END AREA OF EACH SECTION AND FROM THOSE FIGURES DETERMINE THE VOLUME. THIS METHOD HAS BEEN USED FOR MANY YEARS. THE CROSS-SECTIONS HERE WOULD BE THE SAME AS IN ROADWAY CROSS-SECTIONING.

(2) THE ENGINEER ESTIMATES THE BOUNDS OF THE POSSIBLE BORROW AREA, RUNS OUT A CENTERLINE OR BASELINE AS SHOWN ON THE SKETCH, AND DETERMINES THAT CROSS-SECTIONS WILL BE REQUIRED AT VARIOUS PLUSSES DENOTED A, B, C, ETC., N AND P, EACH OF THE LENGTH SHOWN. WHEN THE EXCAVATION IS COMPLETE HE RETURNS AND SIZES UP THE SITUATION. HE NOTES THAT HE WILL NOT HAVE TO REMEASURE TO THE SAME EXTENT HE ORIGINALLY CROSS-SECTIONED BECAUSE THE BOUNDS OF THE PIT ARE LESS THAN HE EXPECTED (REPRESENTED BY LINE W: Z IS THE APPROXIMATE BOTTOM). HE THEN LAYS OUT, ON THE GROUND, THE BOUNDARY LINE "1-2-3-4-5-6-7-8-1". THE BREAKS IN THE BOUNDARY LINE, 2, 3, 4 AND 5, SHOULD BE ON ORIGINAL CROSS-SECTION LINES THAT ARE TO BE REUSED FOR REMEASUREMENT. HE NOTES THAT HE DOES NOT NEED THE PLUSSES AT A AND P. HE NOTES THAT HE WILL NEED CROSS-SECTIONS AT a,b,c,d,e,f,g,h,i,j,v,k,l, m,n,o,p,q,r,s,t, and u TO PROPERLY COMPUTE THE EXCAVATION. HE PROCEEDS TO AMEND THE ORIGINAL GROUNDLINE NOTES BY CROSSING OUT OR CIRCLING THE READINGS BEYOND THE EXTREMITIES OF THE BOUNDARY LINE "1-2-3-4-5-6-7-8-1", AND RECORDING ELEVATIONS WHERE THE LINES C, E, H, I, J AND M INTERSECT THE NEW BOUNDARY LINE; ALSO THE ELEVATIONS AT 1 AND 8 ON LINE B AND 7 AND 6 ON LINE N. THEN HE PROCEEDS TO CROSS-SECTION THE BORROW PIT ON THE LINES NOTED ABOVE, BEING VERY CAREFUL TO TERMINATE EACH SECTION ON THE LINE "1-2-3-4-5-6-7-8-1". HE NOTES A PILE OF WASTED EXCAVATION IN THE CORNER NEAR THE LINE "5-6" WHICH HE ALSO CROSS-SECTIONS ALONG WITH THE EXCAVATION. THE METHOD OF DETERMINATION OF NET QUANTITIES WILL VARY CONSIDERABLY FROM THAT USED IN (1). THIS SYSTEM IS PARTICULARLY ADAPTABLE TO THE ELECTRONIC COMPUTER. A COMPUTER BASE PLANE IS ESTABLISHED A FOOT OR SO ABOVE THE HIGHEST POINT RECORDED IN EITHER ORIGINAL OR REMEASURE NOTES. THEN THE DATA CONCERNING THE ORIGINAL GROUNDLINE IS PROCESSED AND THE VOLUME OF AIR BETWEEN THE BASE PLANE AND ORIGINAL GROUND (LIMITED BY THE LINES "1-2-3-4-5-6-7-8-1") DETERMINED. NEXT, THE REMEASURE DATA IS PROCESSED AND THE VOLUME OF AIR DETERMINED BETWEEN THE BASE PLANE AND THE REMEASURED GROUND (AGAIN LIMITED BY THE LINE "1-2-3-4-5-6-7-8-1"). THE DIFFERENCE IN VOLUMES IS THE NET AMOUNT OF EXCAVATION. THE PILE OF WASTE WILL BE COMPUTED AND DISCOUNTED BUT THE VOLUME WILL NOT BE DISCERNIBLE.

IF THE CONTRACTOR WERE TO EXPAND TO A LARGER AREA THAN ORIGINALLY CONTEMPLATED, THEN THE GROUNDLINE NOTES SHOULD BE EXTENDED ACCORDINGLY. THE FINAL PROCEDURE WOULD BE AS OUTLINED ABOVE.

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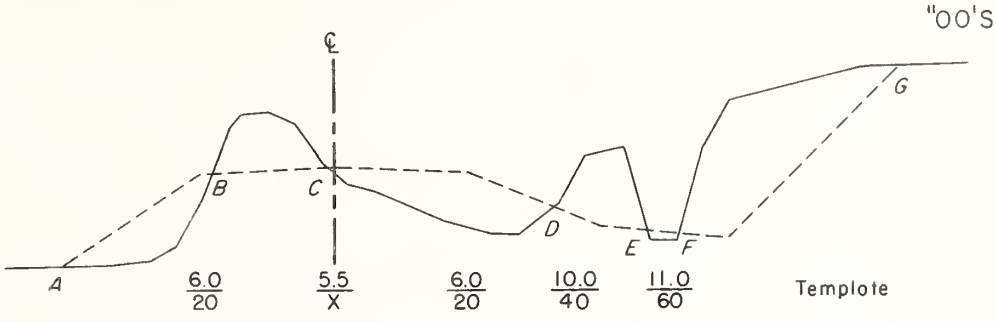
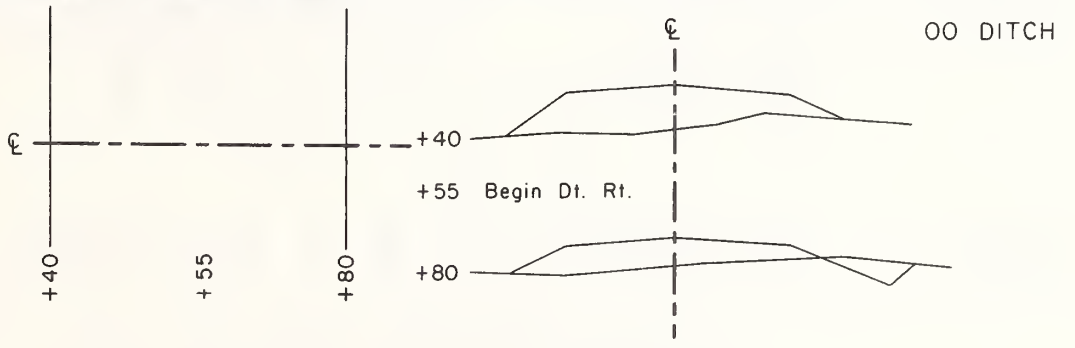
"00'S"



						F0.5									
8.0/20	2.6/16	1.5/14	1.3/10	2.2/6	5.0/2	6.0/X	6.8/2	7.3/6	9.5/16	10.5/24	10.6/28	8.4/32	4.6/38	4.0/44	Ground
			F7.1	F7.3					C13.3	C13.0					
11.4/24	12.6/28	13.0/36	13.1/41.3	13.3/50 R					+2.3/96 R	+2.0/86.0	0.5/60	4.0/56	11.0/52	11.0/48	

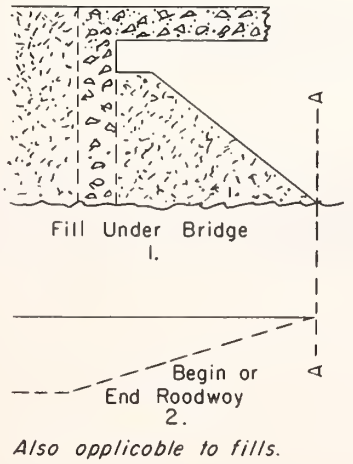
THIS DIAGRAM SHOWS HOW SOME STAKING TIME CAN BE SAVED IF THE ENGINEER IS AUTHORIZED TO TAKE SUCH A SHORT-CUT. IT IS AN ACCEPTED CONTENTION THAT ALL GROUNDLINE BREAKS MUST BE PROPERLY CONSIDERED AND RECORDED IF PROPER QUANTITIES ARE TO BE OBTAINED. THE DIAGRAM SHOWS SEVERAL INTERSECTIONS OF TEMPLATE AND GROUNDLINE. THE RODMAN, UNLESS HIGHLY EXPERIENCED, COULD SPEND CONSIDERABLE TIME IN FINDING THE INTERSECTIONS AT 'B', 'C', 'D', 'E' AND 'F'. WHEN THERE ARE FREQUENT SECTIONS INVOLVED, THE TOTAL TIME CONSUMED IN A DAY WOULD BE QUITE CONSIDERABLE. THE GROUNDLINE SHOWN, OF COURSE, REFLECTS MORE READINGS THAN MOST FOR A NARROW WIDTH. IF THE ENGINEER WERE TO RECORD ALL OF THE BREAKS NECESSARY IN THE GROUNDLINE, ALL OF THE BREAKS IN TEMPLATE, AND THE TWO INTERSECTION POINTS AT 'A' AND 'G', THE ELECTRONIC COMPUTER WOULD FIND ALL OF THE OTHERS DURING THE PROCESS OF AREA DETERMINATION. IT WOULD BE QUITE LIKELY THAT THE ENGINEER WOULD NOT KNOW OF THE TWO "00'S" AT 'E' AND 'F'. IT IS ABSOLUTELY NECESSARY THAT THE TWO OUTSIDE CATCHS, 'A' & 'G', BE FOUND AND RECORDED IN THE FIELD BECAUSE THESE ARE TEMPLATE DATA AS WELL AS GROUNDLINE DATA. THE COMPUTER WILL MAKE THE ENTIRE AREA DETERMINATION IN ABOUT 15 SECONDS. THE ENGINEER IS CAUTIONED, HOWEVER, THAT IN FOLLOWING THE PRACTICE COVERED ABOVE, HE MUST NOT GET 'SLOPPY' AND MUST PUT IN ENOUGH STAKES ALONG THE ROADWAY TO COVER THE REQUIREMENTS OF GOOD CONSTRUCTION. THIS WOULD BE A VERY ADVANTAGEOUS PROCEDURE WHEN CROSS-SECTIONS ARE CLOSELY SPACED.

00 DITCH



THE ABOVE SKETCHES ILLUSTRATE A TYPICAL SITUATION. THESE SKETCHES INDICATE "BEGIN DITCH RIGHT", THE CONDITION COULD BE "END DITCH RIGHT OR LEFT" OR "BEGIN DITCH LEFT". LET IT BE SUPPOSED, IN THIS CASE, THAT THE DITCH WOULD ACTUALLY BEGIN AT +55 ON THE RIGHT. IT IS NECESSARY TO TAKE A CROSS-SECTION AT +55. AN ENTRY IN THE NOTES "BEGIN DT RT +55" WILL NOT SUFFICE. SEE PLATE VII-05-01.

'00' SECTION



Also applicable to fills.

(B) THERE ARE OCCASIONS WHEN IT IS NECESSARY TO SHOW THE END OF A FILL OR END OF A CUT WHERE THE END AREA WILL BE ZERO. TWO EXAMPLES ARE SHOWN AT THE LEFT. THE ROD READINGS IN BOTH CASES CAN BE EITHER ACTUAL OR FICTICIOUS--PROBABLY FICTICIOUS UNDER THE BRIDGE. THE STATIONING SHOULD BE ACTUAL. THE DISTANCE FROM CENTERLINE NEED BE NO CLOSER THAN APPROXIMATE--WITHIN 5 FEET IS CLOSE ENOUGH. THE READINGS ON STATION A ARE SHOWN BELOW.

Case 1.	Templote	5.6/19	4.9/00	4.7/19
	Groundline	5.6/19	4.9/00	4.7/19
Case 2.	Templote	3.2/25	3.2/00	3.2/25
	Groundline	3.2/25	3.2/00	3.2/25

Preceding sections should be token os conditions require.

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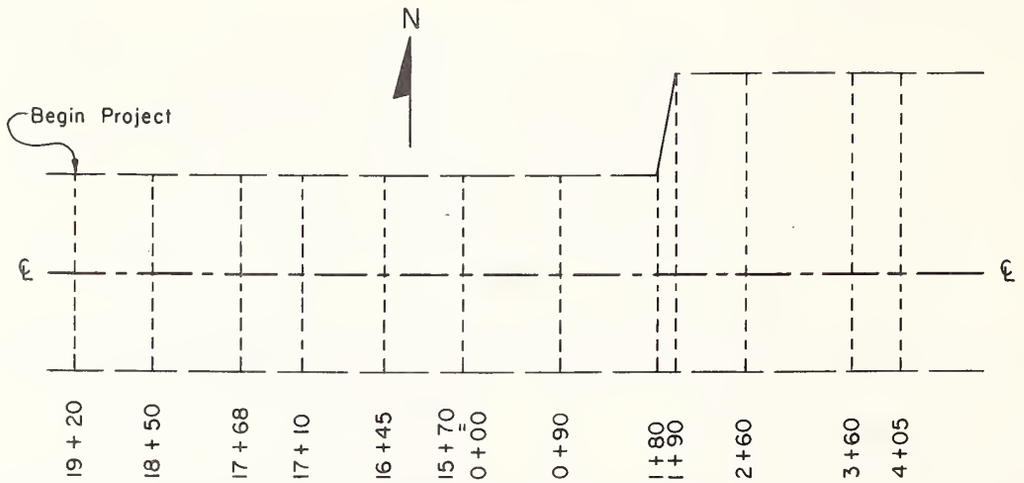
PLATE NO. VII - 05 - 08

DATE APRIL 30, 1973

"MISCELLANEOUS PROBLEMS"



THIS SKETCH IS PREPARED TO REPRESENT SEVERAL SITUATIONS COMMONLY ENCOUNTERED.

1. THE PROJECT BEGINS ON A SURVEY WHICH IS STATIONED FROM EAST TO WEST. THE BEGINNING OF THE STATIONING IS 15+70 WHICH IS EQUAL TO 0+00 ON A SURVEY PROCEEDING FROM WEST TO EAST. CROSS-SECTIONING SHOULD BEGIN AT 19+20 AND RUN EASTWARD THROUGH 18+50, 17+68, 17+10, 16+45, 15+70, 0+00, 0+90, 1+80, ETC., ETC. THEN WHEN THE QUANTITIES ARE WORKED UP THE MASS WILL DEVELOP PROPERLY. THE SAME PROCEDURE WOULD HOLD IF THE STATIONS FROM 19+20 to 15+70 WERE MINUS DISTANCES FROM 0+00, LIKE -3+50, -2+80, -2+08, -1+40, -0+75.

2. THE SURFACING THICKNESS CHANGES 0.8 FT. AT STA. 17+10. THE NOTES WOULD BE RECORDED SOMETHING LIKE THIS:-

H I. 2334.97

17 + 10				6.4		60		6.4	9.4				
29.00				20		X		20	35				
	F5.2		F3.9			F1.2		00		C6.0	C2.6		
	11.2	11.2	10.3	9.3	7.3	7.2	6.9	6.2	3.3	3.4	3.4		
	50	33	25.9	18	6	X	7	10	22	47.0	50		
	R										R		
				7.2		6.8		7.2	9.4				
				21.2		X		21.2	35				
			F 3.1			F0.4	00				C6.0		
17 + 10	11.2	11.2	10.3	9.3	7.3	7.2	6.9	6.9	6.2	3.3	3.4	3.4	
28.02	50	33	25.9	18	6	X	5	7	10	22	47.0	50	

NOTE THAT THE SAME STATION NUMBER IS USED FOR BOTH SECTIONS. THE COMPUTER WILL SUBTRACT THE STATION NUMBER, GET A DISTANCE OF ZERO AND THUS THERE WILL BE NO VOLUME.

3. THE DITCH SECTION IS WIDENED ABRUPTLY AT STATION 1+80--1+90. THE NOTES WOULD BE RECORDED SOMETHING LIKE THIS:

H. I. 2630.00

1 + 80				8.4	4.4	4.0	4.4					
26.00				40	20	X	20					
	C1.1		C2.8		F1.4	F1.6			F4.2	F4.7		
	2.9	3.6	5.6	6.0	5.8	5.6	6.5	8.6	8.6	8.7		
	100	70	45.6	42	27.0	X	14	24	26.3	50		
	R									R		
1 + 90				8.4	4.4	4.0	4.4					
26.00				85	20	X	20					
	C1.1	C5.5			F1.4	F1.6		F4.2				
	2.9	2.9	3.6	6.0	5.8	5.6	6.5	8.6	8.7			
	100	96.0	70	42	27.0	X	14	26.3	50			
	R								R			

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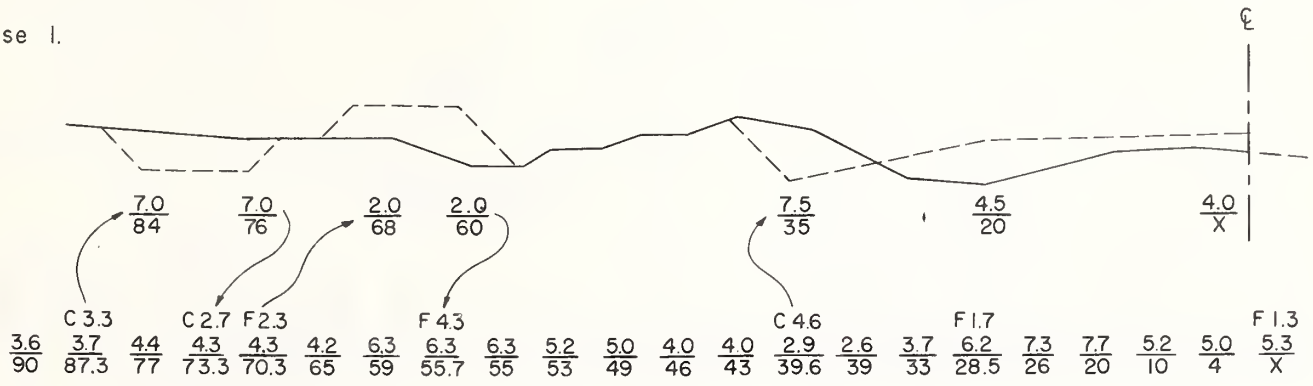
PLATE NO. VII-05-09

DATE APRIL 30, 1973

ROADWAY-CHANNEL CHANGE

Case 1.

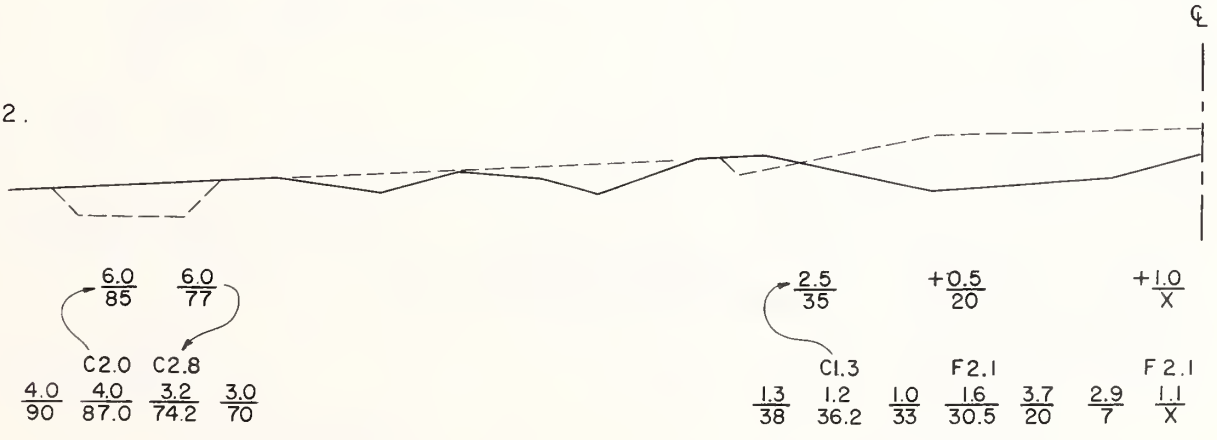


(CASE 1) THIS ILLUSTRATES A CHANNEL CHANGE AND DIKE, WIDELY SEPARATED FROM THE ROADWAY, AND HOW THE NOTES CAN BE RECORDED FOR EASE IN COMPUTER OPERATION. THE TWO SITUATIONS SHOWN ON THIS PLATE ARE THE ONLY ANTICIPATED CASES THAT WILL REQUIRE THE USE OF ARROWS. THE ARROWS CAN BE AVOIDED BY ENTERING IN THE TEMPLATE LINE ALL OF THE INTERSECTIONS OF TEMPLATE AND GROUND FROM 39.6 TO 73.3. IT APPEARS BETTER TO USE THE ARROWS.

THE PUNCH CARD OPERATOR WOULD START THE TEMPLATE READINGS AT 87.3 AND FOLLOW THE ARROWS TO CENTERLINE, AND BEYOND. GROUND WOULD START AT 90 AND BE PUNCHED STRAIGHT THROUGH TO CENTER.

ARROWS MUST POINT FROM LEFT TO RIGHT, REGARDLESS OF WHETHER SECTION IS LEFT OR RIGHT OF CENTERLINE.

Case 2.



(CASE 2) THIS CASE IS SIMILAR TO CASE 1, BUT NO DIKE. IT IS CLEARLY UNDERSTOOD THAT THERE WILL BE NO GRADING DONE BETWEEN 38 AND 70. THE GROUND LINE SHOTS ARE SKIPPED BETWEEN THOSE TWO POINTS. THE TEMPLATE CARD WILL START AT 87.0 AND FOLLOW THE ARROWS TO CENTERLINE, AND BEYOND. THE DASHED LINE BETWEEN 38 AND 70 SHOWS THAT NOTHING WILL BE PUNCHED AS TO TEMPLATE AND GROUND BETWEEN THOSE TWO POINTS. THE SAME PROCEDURES CAN BE APPLIED TO FRONTAGE ROADS.

THERE WILL BE CASES WHERE THE ENGINEER WILL PREFER TO RUN SPECIAL CENTERLINE OR BASE LINE FOR THE CHANNEL CHANGES, ETC.

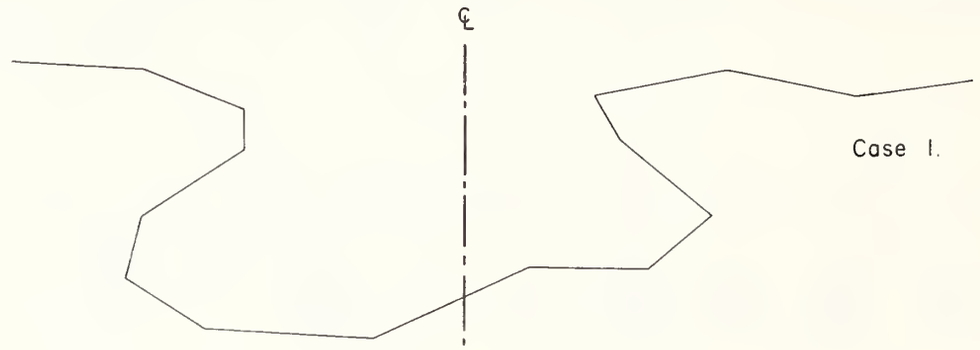
DEPARTMENT OF HIGHWAYS

CONSTRUCTION MANUAL

PLATE VII-05-10

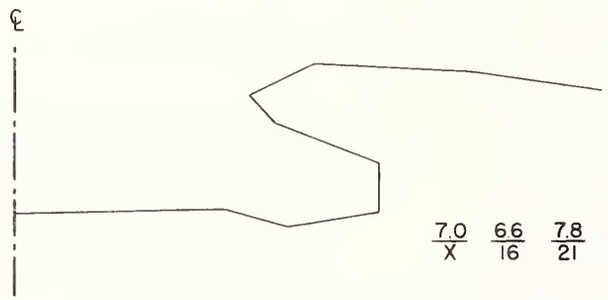
DATE APRIL 30, 1973

OVERHANG



Case 1.

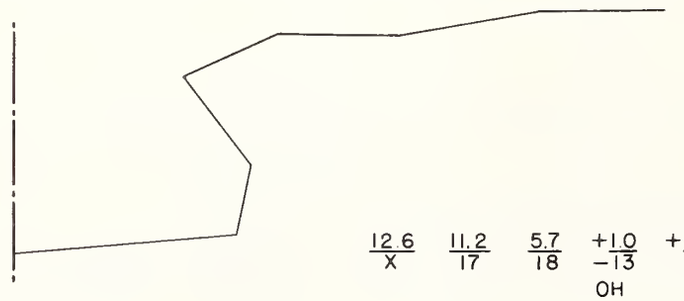
$+\frac{8.5}{35}$ $+\frac{8.0}{25}$ $+\frac{5.1}{17}$ $+\frac{1.8}{17}$ $\frac{3.3}{-25}$ OH $\frac{8.0}{-26}$ $\frac{12.0}{20}$ $\frac{12.7}{7}$ $\frac{9.5}{X}$ $\frac{7.2}{5}$ $\frac{7.5}{14}$ $\frac{3.4}{19}$ $\frac{+2.6}{-12}$ OH $\frac{+6.0}{-10}$ $\frac{+8.0}{20}$ $\frac{+6.0}{30}$ $\frac{+7.2}{39}$



Case 2.

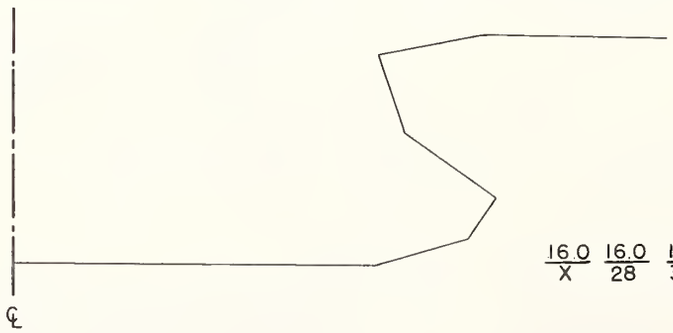
$\frac{7.0}{X}$ $\frac{6.6}{16}$ $\frac{7.8}{21}$ $\frac{6.6}{28}$ $\frac{3.0}{28}$ $\frac{0.0}{-20}$ $\frac{+1.6}{-18.5}$ $\frac{+4.7}{23}$ $\frac{+3.3}{35}$ $\frac{+2.6}{40}$

overhang or (OH)



Case 3.

$\frac{12.6}{X}$ $\frac{11.2}{17}$ $\frac{5.7}{18}$ $\frac{+1.0}{-13}$ OH $\frac{+4.2}{20}$ $\frac{+4.2}{29}$ $\frac{+6.0}{40}$ C 15.5 $\frac{+6.0}{42.8}$ $\frac{+6.0}{50}$



Case 4.

$\frac{16.0}{X}$ $\frac{16.0}{28}$ $\frac{15.4}{30}$ $\frac{14.0}{35}$ $\frac{11.0}{37}$ $\frac{5.0}{-30}$ OH $\frac{+0.2}{-28}$ $\frac{+1.7}{36}$ C 18.0 $\frac{+1.6}{44}$ $\frac{+1.4}{50}$

THIS PLATE ILLUSTRATES HOW NOTES SHOULD BE RECORDED WHEN AN OVERHANG OR CAVE IS ENCOUNTERED.

CASE 1 SHOWS AN OVERHANG ON EACH SIDE OF CENTERLINE. THE NOTES SHOW HOW THE GROUND LINE CAN BE RECORDED SO AS TO DETERMINE QUANTITIES. NOTE THE MINUS DISTANCE READINGS AT 25 AND 26 LEFT OF CENTERLINE AND AT 12 AND 10 RIGHT OF CENTERLINE. ANY HORIZONTAL READING THAT REVERSES, READING FROM THE LEFT, BEARS A MINUS SIGN (-25). THE READINGS AT 25 AND 7 ARE PLUS WITHOUT THE SIGN. WHEN THE RIGHT SIDE IS RECORDED, THE MINUS SIGN OCCURS WHEN THE DISTANCE FROM CENTERLINE DECREASES -- THUS 12 AND 10 SHOULD HAVE A MINUS SIGN. THE MINUS SIGN, IN SUCH CASES, INDICATES A REVERSE DIRECTION IN GROUND LINE AND NOTHING ELSE.

DEPARTMENT OF HIGHWAYS

CONSTRUCTION MANUAL

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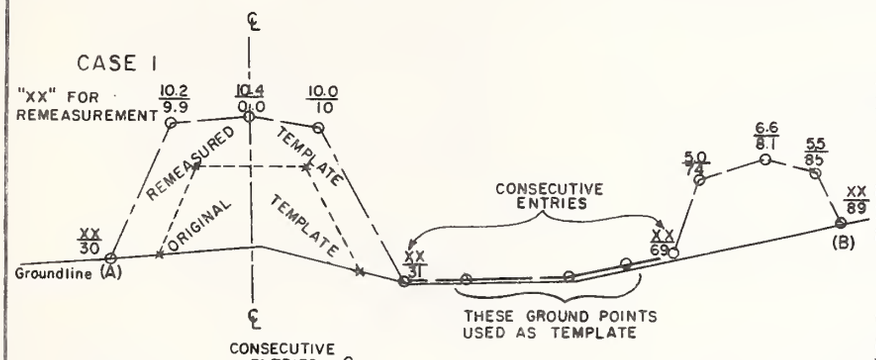
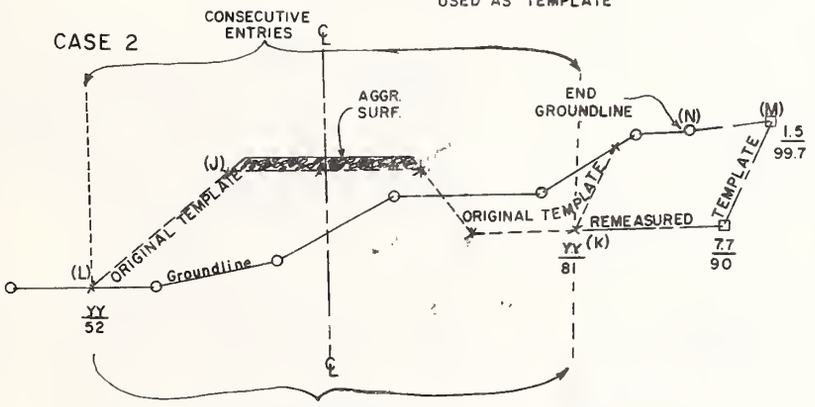
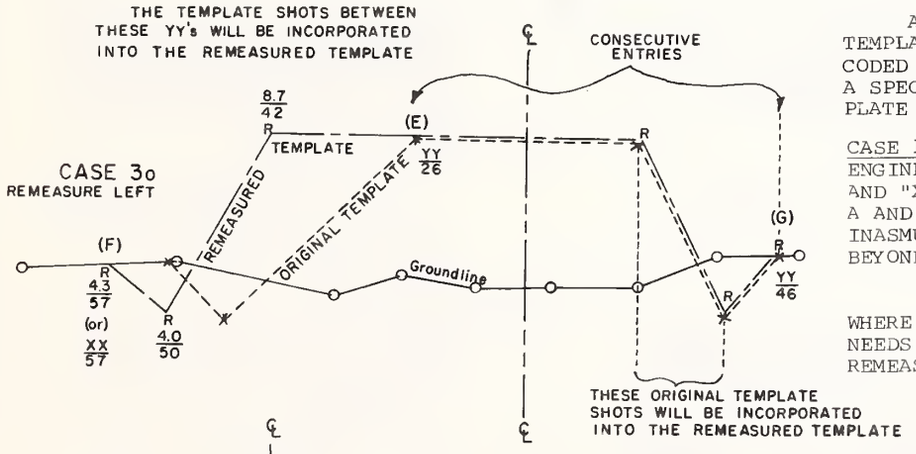
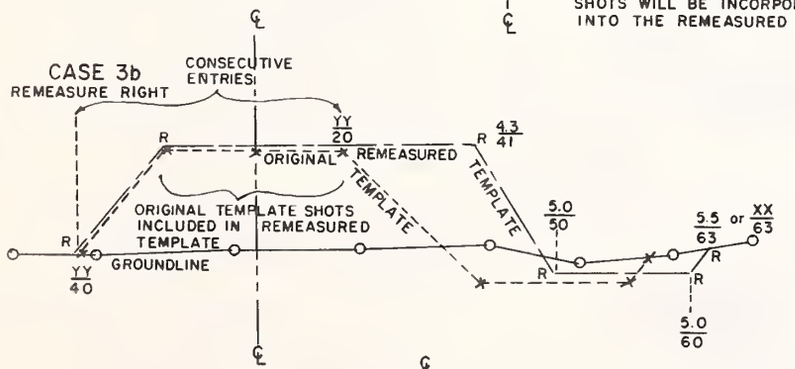
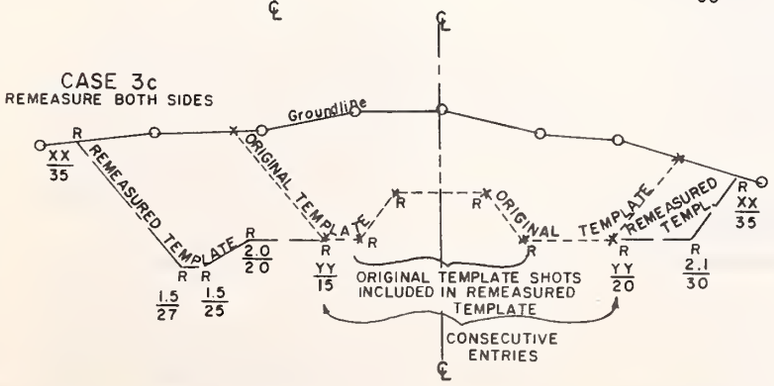
DATE APRIL 30, 1973











REMEASURE

IT WILL BE NECESSARY THAT PARTS OF SOME PROJECTS, AND SOMETIMES ALL, BE REMEASURED IN ORDER TO DETERMINE CORRECT PAY QUANTITIES. IT ALWAYS OCCURS WHEN BORROW PITS ARE USED.

REMEASUREMENT CAN BE CONDUCTED JUST THE SAME AS ORIGINAL CROSS-SECTIONING, ONLY EASIER. IT IS MORE LIKE LOCATION CROSS-SECTIONING. REMEASURE NOTES MUST NOT BE INSERTED INTO THE ORIGINAL GROUNDLINE NOTES.

THE ENGINEER MAY USE ANY H. I. HE WISHES. IT NEED NOT TIE INTO THE CONSTRUCTION STAKING H. I. IT IS NECESSARY, HOWEVER TO REMEASURE AT THE SAME STATIONS AT WHICH CONSTRUCTION STAKING WAS CROSS-SECTIONED. IF IT IS NECESSARY (E.G., ROCK WORK) TO ADD SOME NEW SECTIONS ON REMEASURE THAT WERE NOT IN THE ORIGINAL STAKING, THE FIELD ENGINEER MUST INTERPOLATE THE GROUNDLINE SECTIONS. INTERPOLATED SECTIONS SHOULD BE SUBMITTED AS SUPPLEMENTARY NOTES.

AN "XX" CODED INTO A TEMPLATE SECTION WILL CAUSE THE COMPUTER TO INTERPOLATE AN ELEVATION FROM THE GROUNDLINE DATA AT A CERTAIN DISTANCE. THE USE OF "XX" RODS HAS NO RESTRICTIONS AS TO NUMBER, PLACE, OR ORDER PER SECTION. "XX" MAY BE USED IN EITHER ORIGINAL TEMPLATE NOTES OR REMEASURE NOTES.

A "YY" ROD MAY BE USED IN REMEASURED TEMPLATE NOTES ONLY. "YY" RODS MUST BE CODED IN PAIRS IN ORDER TO INCORPORATE A SPECIFIED PATTERN OF THE ORIGINAL TEMPLATE INTO THE NEW REMEASURED TEMPLATE.

CASE 1. THIS IS A NORMAL CASE WHERE THE ENGINEER ELECTED TO USE DISTANCES ONLY AND "XX" FOR RODS, AT THE CATCH POINTS, A AND B. THIS IS COMPLETELY IN ORDER INASMUCH AS THE GROUNDLINE EXTENDS BEYOND THE REMEASURED SECTION.

THE LAST SHOT RIGHT AND LEFT, WHERE GROUND AND REMEASURE INTERSECT NEEDS DISTANCE ONLY, PROVIDING THE REMEASURE SECTION IS COINCIDENT WITH AN ORIGINAL GROUNDLINE SECTION AND FURTHER PROVIDING THAT ORIGINAL GROUND NOTES GO FARTHER OUT THAN THE REMEASURE SECTION. IT IS BEST, INSTEAD OF ENTERING A ROD READING, TO WRITE "XX" AS SHOWN.

NOTICE THE TWO CONSECUTIVE "XX" READINGS AT XX/31 AND XX/69. THESE ENTRIES WILL CAUSE THE COMPUTER TO USE THE GROUNDLINE SHOTS BETWEEN THE "XX'S" AS TEMPLATE.

CASE 2. WHEN THE REMEASURE SECTION EXTENDS FARTHER FROM CENTERLINE, EITHER SIDE THAN THE ORIGINAL GROUNDLINE NOTES RECORD, THEN BOTH ROD READING AND DISTANCE ARE NECESSARY AT (M). THE COMPUTER WILL CONNECT POINTS (N) AND (M) AUTOMATICALLY AND DETERMINE THE END AREA. SUCH A READING AS 1.5/99.7 IS NECESSARY. THE USE OF XX/99.7 RESULTS IN NO PROGRESS.

WHEN THE ROADWAY SURFACE IS COVERED WITH GRAVEL (E.G.) AND IS INACCESSIBLE FOR REMEASURE READINGS, THE USE OF "YY" IS ACCEPTABLE, SUCH AS YY/52 AND YY/81 AT (L) AND (K). THE DISTANCE MUST BE THE SAME AS IN THE STAKED TEMPLATE NOTES. THE USE OF "YY" IN THE REMEASURE NOTES WILL TELL THE

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PLATE NO. VII – 05 – 11 A

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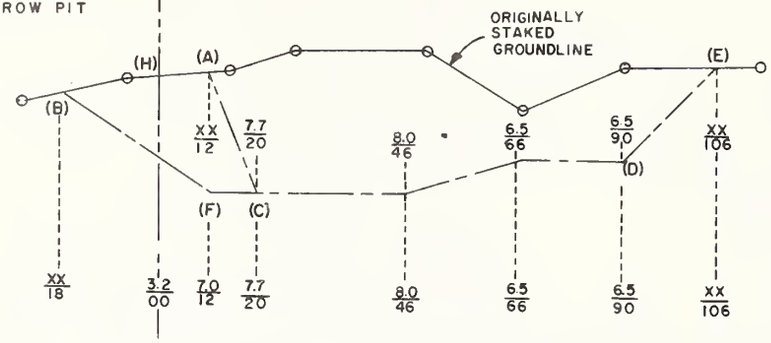
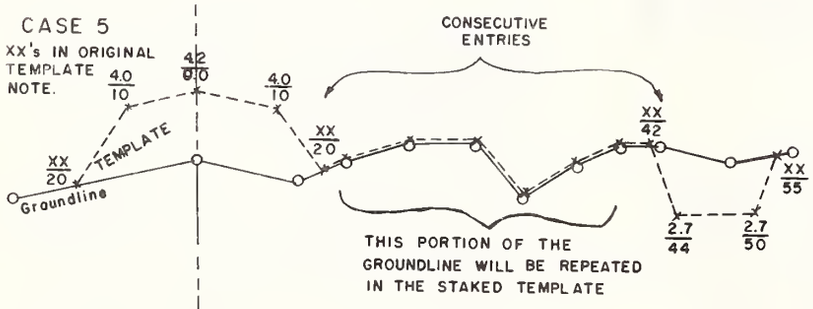
CASE 4

BORROW PIT

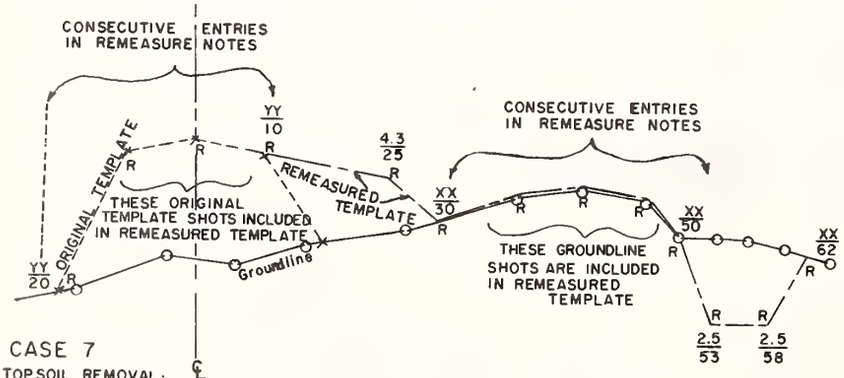


CASE 5

XX's IN ORIGINAL TEMPLATE NOTE.

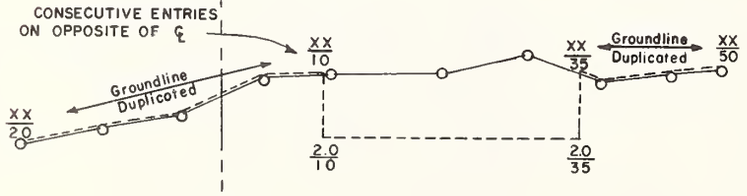


CASE 6



CASE 7

TOPSOIL REMOVAL; SUB-CUT



NOTE: ℄ COULD VERY WELL HAVE BEEN LOCATED IN THE SUBCUT. IN THAT CASE XX LOCATION AND USE WOULD BE SIMILAR TO PREVIOUS CASES.

COMPUTER TO USE THE STAKED TEMPLATE NOTES BEGINNING WITH THE FIRST "YY" AND ENDING WITH THE NEXT "YY". (BEGIN YY/52, END YY/81). ALL ACTUAL REMEASURE READINGS (ROD/DISTANCE OR XX/DISTANCE) MUST BE FARTHER FROM CENTERLINE, EITHER SIDE, THAN A "YY" READING.

THE USE OF YY READINGS IS NOT PERMISSIBLE IF THE FINISHED ROADWAY IS NOT IN CONFORMITY TO THE ORIGINAL TEMPLATE.

CASE 3 - A. B. & C. THIS ILLUSTRATES ANOTHER SITUATION THAT COULD HAPPEN ON EITHER SIDE OF CENTERLINE. THE LEFT SIDE, CASE 3-A, NEEDS REMEASURE BUT THE RIGHT SIDE DOES NOT, BECAUSE IT WAS CONSTRUCTED IN CONFORMITY TO THE ORIGINAL TEMPLATE. THIS IS INDICATED BY THE SUGGESTED TYPICAL NOTES. LIKEWISE THE READING AT (F) COULD BE XX/57 INSTEAD OF 4.3/57. CASE 3-B, IS SIMILAR TO CASE 3-A. REMEASURE IS REQUIRED ONLY ON THE RIGHT SIDE. CASE 3-C, ILLUSTRATES REMEASURE ON BOTH SIDES OF CENTERLINE.

CASE 4. THIS ILLUSTRATES A BORROW PIT THAT WAS ORIGINALLY CROSS-SECTIONED ON BOTH SIDES OF A BASE-LINE OR CENTERLINE. WHEN EXCAVATION WAS COMPLETED, THE REMEASURE SECTION LOOKED LIKE ACDE. "XX" CAN BE USED AT (E), XX/106 AND AT (A), XX/12.

IF THE REMEASURED SECTION WERE REPRESENTED BY BFCDE, THEN "XX" COULD HAVE BEEN USED AT (B), AS XX/18 or 4.0/18, AS THE ENGINEER DECIDES.

CASE 5. THIS ILLUSTRATES THE USE OF "XX'S" IN THE ORIGINAL TEMPLATE NOTES. NOTICE THAT "XX'S" ARE CONSECUTIVE ENTRIES AND ARE BOTH ON THE SAME SIDE OF CENTERLINE.

CASE 6. IS AN EXAMPLE OF THE JOINT USE OF "XX" AND "YY".

CASE 7. SHOWS THE USE OF "XX" FOR TOPSOIL REMOVAL, SUB-CUT, ETC.

NOTE: ONLY THOSE ENTRIES SHOWN ON THE EXAMPLE DRAWINGS (CASES 1-7) HAVE TO BE INCLUDED IN THE ENGINEER'S ACTUAL NOTES.

REMEMBER

1. "XX" MAY BE USED AS A ROD READING ANYWHERE ON THE SECTION.
2. "XX'S" MAY BE RECORDED CONSECUTIVELY IN THE CROSS-SECTION NOTES.
3. "XX" CAN BE USED ANY NUMBER OF TIMES ON THE SAME SIDE OF CENTERLINE PER SECTION.
4. "YY" CAN BE RECORDED IN REMEASURED TEMPLATE NOTES ONLY.
5. "YY'S" MAY BE CODED IN PAIRS ONLY.
6. "YY" MAY LIE ANYWHERE ON THE STAKED TEMPLATE AS LONG AS IT IS USED ONLY ONCE ON THE SAME SIDE OF CENTERLINE.

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CONSTRUCTION MANUAL

PLATE NO. VII - 05 - 12

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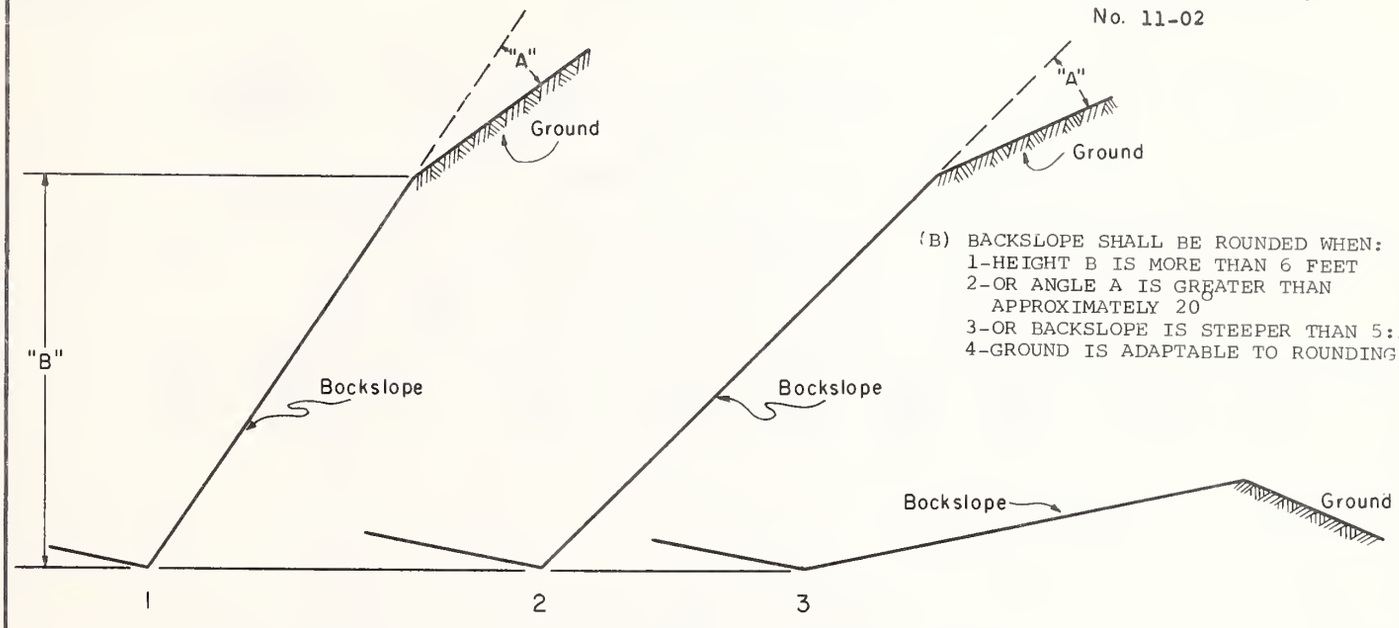
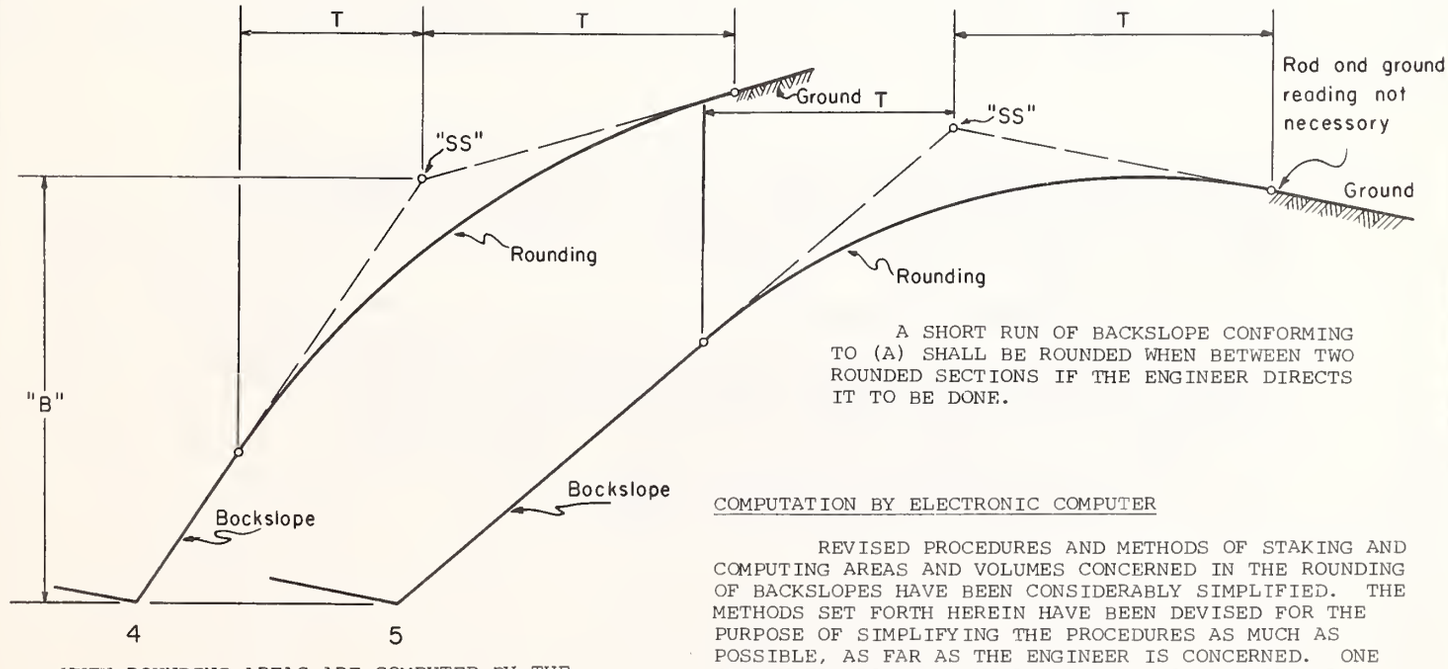
SAMPLE CONDITIONS

"BACKSLOPE ROUNDING"
See Standard Drawing
No. 11-02



(B) BACKSLOPE SHALL BE ROUNDED WHEN:
1-HEIGHT B IS MORE THAN 6 FEET
2-OR ANGLE A IS GREATER THAN APPROXIMATELY 20°
3-OR BACKSLOPE IS STEEPER THAN 5:1
4-GROUND IS ADAPTABLE TO ROUNDING

(A) BACKSLOPE SHALL NOT BE ROUNDED WHEN:
1-HEIGHT B IS 6 FEET OR LESS
2-OR ANGLE A IS LESS THAN APPROXIMATELY 20°
3-OR BACKSLOPE IS 5:1 OR FLATTER
4-OR NATURAL SOIL IS ROCK, HEAVY GRAVEL OR OTHERWISE UNADAPTABLE



A SHORT RUN OF BACKSLOPE CONFORMING TO (A) SHALL BE ROUNDED WHEN BETWEEN TWO ROUNDED SECTIONS IF THE ENGINEER DIRECTS IT TO BE DONE.

WHEN ROUNDING AREAS ARE COMPUTED BY THE ELECTRONIC COMPUTER, THE PROGRAM IS SO ARRANGED THAT, IF THE DISTANCE FROM THE SLOPE STAKE (SS) TO THE FARTHEST READING FROM CENTERLINE IS LESS THAN T DIST., THE EXTENT OF ROUNDING WILL BE LIMITED TO THAT DISTANCE (E.G.--SS TO LAST SHOT = 3', ROUNDING WILL BE 3 x 3).

IT IS NOT NECESSARY, AS FAR AS AREA COMPUTATIONS ARE CONCERNED, TO TAKE A ROD AND GROUND READING AT THE OUTSIDE EXTENT OF ROUNDING.

THE ENGINEER WILL STAKE BEGINNING AND ENDING OF EACH SECTION OF ROUNDING, WITH LATH OR STAKES OR OTHER SUITABLE MEANS, FOR THE CONTRACTOR"S GUIDANCE.

COMPUTATION BY ELECTRONIC COMPUTER

REVISED PROCEDURES AND METHODS OF STAKING AND COMPUTING AREAS AND VOLUMES CONCERNED IN THE ROUNDING OF BACKSLOPES HAVE BEEN CONSIDERABLY SIMPLIFIED. THE METHODS SET FORTH HEREIN HAVE BEEN DEVISED FOR THE PURPOSE OF SIMPLIFYING THE PROCEDURES AS MUCH AS POSSIBLE, AS FAR AS THE ENGINEER IS CONCERNED. ONE CASE WHERE ROUNDING WOULD NOT BE REQUIRED OR PERFORMED, NOT SHOWN HEREON, IS THAT OF INSUFFICIENT RIGHT-OF-WAY WIDTH. THE COMPUTER WILL COMPUTE ROUNDING QUANTITIES IN ACCORDANCE WITH THE DESIGN SHOWN HEREON.

IT IS NOT NECESSARY TO TAKE A READING AT A POINT "T" DIST., BEYOND THE SLOPE STAKE JUST BECAUSE OF ROUNDING. THE COMPUTER WILL MAKE THE COMPUTATION WITHOUT THAT IF THERE IS A READING BEYOND THE SLOPE STAKE -- IT SHOULD BE AT LEAST TEN FEET, IF POSSIBLE.

IF THE ENGINEER WANTS ROUNDING QUANTITIES COMPUTED, HE MUST SAY SO IN HIS LETTER OF TRANSMITTAL; OTHERWISE THE COMPUTATION WILL NOT BE MADE. IF THERE ARE ANY EXCEPTIONS, LIKE STATION XX TO STATION YY, LEFT OR RIGHT, HE MUST SO STATE.

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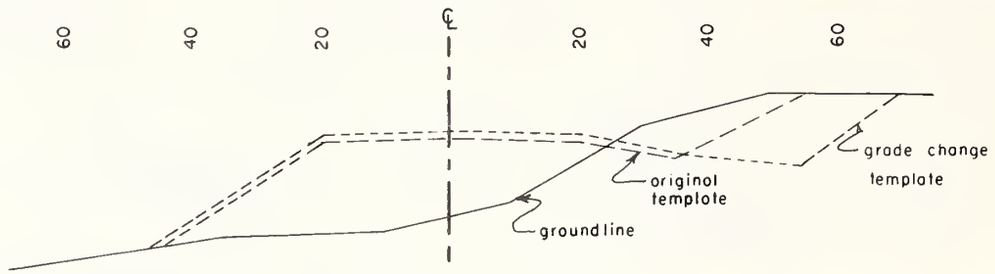
PLATE NO. VII - 05 - 13

DATE APRIL 30 , 1973

GRADE CHANGE



Sample originol staking notes.

Template			10.4 / 20		10.0 / 0		10.4 / 20		13.4 / 35			
Ground	30.3 / 68 R.P.	F16.6 / 27.0 / 44.9 1½:1	25.5 / 35	24.5 / 10	F12.2 / 22.2 / 0	20.0 / 10	F1.2 / 11.6 / 26.0	8.5 / 30	3.4 / 50	C10.0 / 3.4 / 55.0 2:1	3.4 / 76 R.P.	

SAMPLE GRADE-CHANGE NOTES

USE THE FOLLOWING PROCEDURE ONLY WHEN GROUNDLINE NOTES HAVE ALREADY BEEN PUNCHED

TEMPLATE	F18.0 / 27.4 / 47.0 1½:1	9.4 / 20	9.0 / 0	9.4 / 20	12.4 / 35	14.4 / 55	C11.0 / 3.4 / 71.5 1½:1

THIS ILLUSTRATES THE ENTRY OF THE TEMPLATE NOTES, AND THESE ONLY, IN AND ON ENTIRELY DIFFERENT PAGES OF THE NOTEBOOK. THE GROUNDLINE NOTES ARE NOT AMENDED IN ANY WAY. THE SLOPE STAKE READINGS FOR THE TWO OUTSIDE CATCHES ARE ENTERED INTO THE TEMPLATE BLOCK RATHER THAN INTO THE GROUNDLINE BLOCK. THE INSIDE CATCH AT 26.0' RIGHT COULD BE ENTERED INTO THE NEW TEMPLATE NOTES, BETWEEN 20' AND 35' RIGHT, IF THE ENGINEER SO DESIRES.

NOTATION MUST BE MADE, IN THE ORIGINAL NOTES, THAT A GRADE CHANGE HAS BEEN MADE.

THE NEW TEMPLATE NOTES MUST BE PROPERLY IDENTIFIED AND SUPPLEMENTED BY SUCH INFORMATION AS STATION, GRADE, H.I., AND ANY OTHER PERTINENT DATA. ANY H.I. MAY BE USED FOR THE REVISED TEMPLATE SINCE THE MACHINE WORKS WITH TRUE ELEVATIONS. THE SAME H.I. WAS USED HERE FOR EASE OF COMPARISON ONLY.

IF REVISED QUANTITIES ARE REQUIRED, SEND THE NEW NOTES TO HELENA FOR COMPUTATION. THEY WILL BE BLENDED WITH THE ORIGINAL NOTES.

STATE OF MONTANA
DEPARTMENT OF HIGHWAYS

30-180

DPS E-10-C

EQUATIONS AND BRIDGES

× IDENT. NO. | 10 (cols 6–7)

Date _____

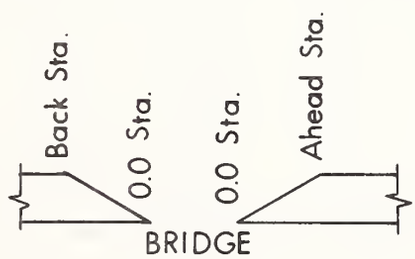
Project No. _____ Coded By _____ Data Checked By _____

EQUATIONS

Back Station * (8–16)	Ahead Station * (17–25)	Line

EQUATIONS

Back Station * (8–16)	Ahead Station * (17–25)	Line



× IDENT. NO | 11 (cols 6–7)

Bridge or Begin And End Stations

Back Station Toe * (8–16)	Ahead Station Toe * (17–25)	Line

Back Station Toe * (8–16)	Ahead Station Toe * (17–25)	Line

* All Equations Require A Cross-section

× By Data Processing Section

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STATE OF MONTANA
DEPARTMENT OF HIGHWAYS

BACKSLOPE ROUNDING

× IDENT. NO. | 1 5 (1 … 5 6 7)

Project No. _____ Coded By _____

Data Checked By _____ Date _____

* FROM STATION (8 9 … 16)	* TO STATION (17 … 25)	L or R (26 27)	LINE (79 80)

* All Equations Require A Cross-section

× By Data Processing Section Only

NOTE: Code A "-1", "0", or "1" in Column 27
TO SPECIFY RND'G LEFT, BOTH, OR RIGHT.
UP TO 60 RND'G CARDS MAY BE CODED.

STATE OF MONTANA
DEPARTMENT OF HIGHWAYS
HELENA, MONTANA

CONSTRUCTION DATA TRANSMITTAL SHEET

For Data Processing
Submit In Duplicate

Project No. _____

Designation _____

Mgr. F.P.U. _____

Date _____

By Data Processing Section Only

Recd. DPS	Compl. DPS

Are notes being submitted for this processing ? ☐ Yes ☐ No

What type ? ☐ Original ☐ Remeasure ☐ Extensions

☐ Other _____

_____

_____

CODE SHEETS SUBMITTED

(List the code sheets by Form No and give the total number of sheets submitted)

DPS FORM NO.	NO. OF SHEETS

Total no of sheets _____

Type of computation requested : ☐ Areas & Volumes ☐ Emb + ☐ Mass

☐ Station Yards ☐ Backslope Rounding Remarks _____

_____

Area No.	Class	Project	Agree	Unit	Work	Control	Comm
						9402	177

Rev. 5-1-73

STATE OF MONTANA
DEPARTMENT OF HIGHWAYS

30-18R DPS-E40-C

Project No. _____ Coded By _____ Data Checked By _____ Date _____

× COMPACTION FACTORS

IDENT. NO.	
	40

1 5 6 7

× BALANCE POINTS

IDENT. NO.	
	41

1 5 6 7

CODE TO COLUMN 16 ONLY.

* STATION 8 9 16	17	CODE 18	FACTOR 19 24	STANDARD FACTOR TABLE 1.45 25 27	1.35 28 30	1.25 31 33	1.15 34 36	1.10 37 39	LINE 79 80

* All Equations Require A Cross section
× By Data Processing Section Only

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COLUMN 18 CODING: (COMPACTION CARDS ONLY)
STANDARD FACTORS
ADJUSTED STANDARD (CODE ADJ. IN COLS. 19-24)
MODIFIED TABLE (CODE NEW TABLE IN COLS. 25-39)
CONSTANT FACTOR (CODE FACTOR IN COLS. 19-24

STATE OF MONTANA
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ADDED QUANTITIES

Note: Forced Balance Run Only.
NF (Col. 33) Usually blank or Zero.
Code NF = 1 if Admass has already been factored.

× IDENT.NO. 4 2
1 5 6 7

Project No _____ Coded By _____ Data Checked By _____ Date _____

* STATION 8 9 16	CUT 17 24	FILL 25 32	N F 33	HAUL DISTANCE 34 38	REMARKS 39 71	LINE 79 80
+						
+						
+						
+						
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* All Equations Require A Cross-section
× By Data Processing Section Only

30-18S

Rev. 5-1-73

30.08 Precision, Accuracy, and Tolerances

In general the accuracy of horizontal and vertical controls is to conform to recognized standards for accuracy, with the degree of accuracy consistent with the intended use.

A. Vertical Control

The error of closure in establishing or checking bench marks is to be mo more than 0.02 of a foot. An error of closure on the bench mark of 0.05 of a foot is allowable for such level work as taking cross-sections, setting grade stakes, and slope staking.

The accuracy of reading the level rod should be as shown below for the type of work intended.

1. 0.01 of a foot for setting grade for forms, structure, pavements, curbs, gutters, walls, rails, etc.

2. 0.05 of a foot when setting subgrade stakes (bluetops).

3. 0.1 of a foot when reading ground elevations for cross sectioning and setting of slope stakes.

B. Horizontal Control

If measurements are to be consistent, it is evident that the accuracy of angles should correspond with the accuracy of the related distances. Therefore, the percentage of angular error should equal the percentage of error in distance, whenever this equality is practical. The ratio of linear error in highway work should be equivalent to third order surveying. This is one foot in five thousand feet. The angular error should also correspond to third order work. The following table shows ratios of accuracy from one foot in 344 feet to one foot in 206,000 feet. The various angular errors corresponding to ratios of accuracy are determined for a length of 1,000 feet. For a length other than 1,000 feet the linear error is in direct proportion to the angular error. An example illustrating the use of this table is as follows: Assume that distances are to be chained with an accuracy of 1 in 5,000; the corresponding permissible angular error would then be 30 seconds.

Angular Error	Linear Error in 1,000 Ft.	Ratio of Accuracy
10' 00"	2.9089	1/344
04' 00"	1.4544	1/688
01' 00"	0.2909	1/3,440
30"	0.1454	1/6,880
20"	0.0970	1/10,300
10"	0.0485	1/20,600
05"	0.0242	1/41,200
01"	0.00484	1/206,600

Table II-1

In most of the survey work done the distances are accurately determined to the proper accuracy whereas angles are measured more or less to the desired accuracy without increased loss of time or effort.

The standard steel tape "chain" is manufactured to provide accurate measurements of 100 feet when the air temperature is 68° Fahrenheit and when the chain is supported or pulled to the specified tension. The magnitude of changing length is related to the coefficient of thermal expansion. The coefficient of expansion for a steel tape is 0.00000645 feet per foot for each degree above or below 68° Fahrenheit. The change in length of the tape from the standardized temperature of 68° Fahrenheit can be easily calculated from the following formula. The table below may also be used:

$$l = L + Lct$$

Where l = change in length of steel tape

L = full length of steel tape, usually 100'

c = coefficient of expansion, 0.00000645

t = difference between 68° F. and temperature of the tape

The following table has been included for ease of computing temperature corrections. The general roadway survey will not require temperature corrections; however, each engineer should compare the daily temperatures with the work he is doing and the accuracy required for that work before he chooses not to use a temperature correction.

TABLE OF TEMPERATURE CORRECTION

For 100 Ft. Steel Tape Standardized at 68° F.

Chain has shortened		Chain has lengthened	
-30°	0.0631	68°	0.0000
-25°	0.0599	70°	0.0013
-20°	0.0568	75°	0.0045
-15°	0.0536	80°	0.0077
-10°	0.0503	85°	0.0110
- 5°	0.0471	90°	0.0142
0°	0.0439	95°	0.0174
5°	0.0407	100°	0.0206
10°	0.0374	105°	0.0239
15°	0.0342	110°	0.0271
20°	0.0310		
25°	0.0277		
30°	0.0245		
35°	0.0213		
40°	0.0181		
45°	0.0148		
50°	0.0116		
55°	0.0084		
60°	0.0052		
65°	0.0019		
68°	0.0000		

Note: When measuring between two established points, add temperature corrections above 68° F. to measured distance and subtract below 68° F.

When laying out a given distance, subtract temperature correction above 68° F. and add below 68° F.

Table III-2

Errors caused by excessive sag can be compensated for by duplicating the pull or tension at which the tape was standardized, usually about 10 pounds, with the tape supported for its full length.

30.09 Land and U.S. Survey Monuments

Highway construction frequently cuts through or fills areas containing section corners, subdivision corners, U.S. bench marks, or other similar monuments. Engineers should take steps to preserve all existing corners during construction and to set permanent markers or witness markers after the work is completed. Monuments, corners, and similar survey points should be thoroughly and completely protected during the course of construction operations. Steps should be taken by the engineer to preserve or reset all U.S.C. & G.S., B.L.M., or other agency bench marks, triangulation points, land monuments, and all permanent markers found on the project.

The plans should be examined for location of section lines, or subdivision lines, crossing or intersecting other lines within the limits of the right-of-way. The plans may indicate the location of land monuments. Notations should be made in field notebooks of the indicated monuments and land line intersections so the locations may be investigated for existing monuments.

Most counties in Montana do not have a county surveyor or county engineer; however, for those counties that do, the county surveyor should be asked to witness the referencing in preparation for resetting a section corner or similar land monuments. Only the Judge can establish a section corner, but the engineer can perform the survey and must have these notes properly recorded in the Court House. Referencing of land monuments should include at least three substantial tie points, sufficiently removed so there is no chance of their being destroyed during construction operations. When no monument is visible, investigation should be made to determine positively that it is not buried. Monuments to be re-established in gravel roads should be set about 6 inches below the finished grade. A metal marker such as a railroad spike should be inserted flush with the surface of pavement on paved roads, and a cross chiseled or filed on its top to show the center of the monument. Careful notes should be kept of the references, which include description of corners found and referenced. The notes should be witnessed by the signatures of two or more persons. A record is to be filed with the County Clerk & Recorder as soon as monuments have been set.

U.S.G.S. Monuments: The U.S. Geological Survey Monuments may serve as a level monument or a transverse monument; or one monument may contain both level and transverse information. Notify the United States Department of the Interior, Geological Survey, in the event that it is necessary to move one of their monuments. The notification should give the general description of the area in which the monument is located and the description stamped on the bronze plate. The U.S.G.S. will then either send a party to move it, or send forms on which to enter a description of the new location and field notes for revision of the data. The accuracy of level monuments should be preserved by recording the difference in elevation from the old location to the reset location in thousandths of a foot: The true bearing of traverse monuments to be reset should be determined to the nearest one-half degree with the horizontal distance to the nearest one-tenth of a foot from the old to the new location. Where the true bearing is not available, reference the monument accurately so the exact location can be re-established. Send this information to the U.S.G.S.. They can then reset the monument with their own forces.

U.S. Coast and Geodetic Monuments: When a U.S.C. and G.S. monument is found, and will be disturbed by construction, immediately notify the Director, Coast and Geodetic Survey, U.S. Department of Commerce, Washington 25, D.C., by letter. Send a copy of this letter to the U.S. Department of the Interior, Geological Survey, and a copy to the Division Office. The letter should state the reason for wanting to move the monument, a general description of the area in which it is located, the designation stamped on the bronze plate and contain a pencil rubbing of the plate. If it is urgent that the monument be moved at once, request a hurried reply to the letter. Full instructions will be sent for resetting the monument. After the monument is reset, send the requested data to the U.S.C. & G.S. office.

30.10 Survey Notes - General

All field notes should be recorded on standard field notebook paper which is available by requisition from the Division office.

The construction survey notes cover alignment, bench marks, cross section, grade stakes, slope stakes, stakes set for structures, and miscellaneous construction survey data. Survey entries should be the original entry. They are not to be taken on scratch paper for copying at a later date. All notes shall show the name of the person making the notes, the person doing the checking, the date for each day, the party personnel, and weather information. Symbols may be used to designate the person running the instrument, doing the chaining, rodding work, or other survey duties.

Each notebook should be identified on the front cover by subject, alignment, cross sections, etc. project number and the name of the Project Manager. On small projects some of the separate operations and miscellaneous survey notes may be combined in a single notebook, whereas larger projects may require separate notebooks for each operation. Notebooks that contain many different types of survey data should contain an index in the front page stating the book's contents.

Notes should be legible and recorded so that other engineers may readily interpret any part. Avoid erasures, make revisions or deletions by crossing through the deleted part and placing the correct entry near by.

The transit book should contain complete information of the constructed center line or other lines run, reference for control points, and any errors found in angles or chain and the corrections made thereto.

Check levels should be run on existing bench marks. If errors are found, corrections should be made and new descriptions for the bench marks established and recorded in the level book with the proper cross referencing to the original level data. Bench marks that will be disturbed during construction must be replaced outside construction limits and the proper records made.

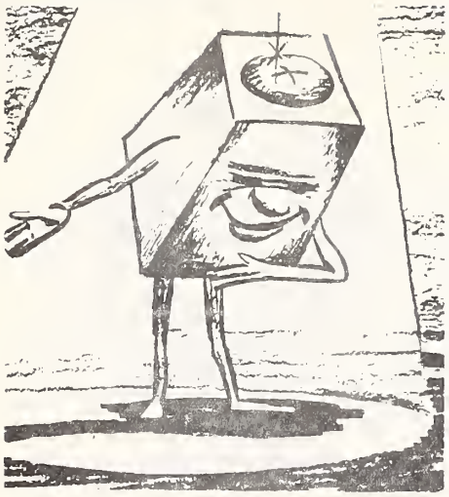
30.11 Checking Plans

The preliminary review of the plans for the project should be made in the field before any staking is started. A very careful check should be made to assure that drainage facilities are located properly and that drain pipes are of sufficient size to transmit the expected runoff. The location of all farm approaches and business entrances or residences should be checked. Notations can be made for any additional requirements necessary to serve new properties which have not been shown on the plans but which may have been in existance at the time right-of-way was secured. No additions, deletions, or revisions should be made to any entrances or condemned property or to controlled access of right-of-way without the approval of the Division Supervisor and the Construction Bureau.

30.12 Co-operation with Contractor

The Project Manager should consult the contractor as soon as possible after the project is awarded to co-ordinate the staking plans with the contractor's work schedule. These discussions may be held before the Preconstruction Conferences and if so, the plans should be reaffirmed at the Preconstruction Conference. The need to retain referenced control points and the possible cost to the contractor in terms of stake replacement and work delay awaiting new stakes may be completely discussed with the contractor.

If there is any doubt of full understanding of the staking method, stake markings, staking schedules, protection of control points or the State's intention to keep re-staking to a bare minimum, write a letter of explanation to the contractor. This written record may become a valuable aid in the event that portions of the work are not built to the established lines and grades.



U.S. DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY
WASHINGTON 25, D C

INTRODUCING MARVIN MARKER

My name is Marvin Marker. I belong to an extremely large family of bronze station markers which are property of the U. S. Coast and Geodetic Survey. Because of my 150-year's longevity, I wos chosen to solicit your help in a serious fomily problem.

Our problem is the some os that faced by people throughout the world today -- SURVIVAL. Yet our concern, apart from man's, is not becouse of the present world situation. Our chances of survival are slim regordless of the world's condition! And they are getting slimmer all the time! That's why I om appealing to you.

Lately our lineage has suffered terrifically becouse of premature deoths. Lost yeor, thousands of Markers met with ill-fated deaths. Hundreds were mistreated, abused, uprooted and thrown oway. Some were even brutolly murdered. Few, I om sorry to say, ever die comfortobly of old age.

Although I am emotionally involved os a member of the family, I con't help but think that people, too, would become a bit emotional if they knew the terrific expense involved in replocing us. Someone told me that the Government spends thousands of dollars each year just replacing unfortunate Markers. (Boy! That sounds like on owful lot of the people's money, since they're alwoys complaining about not having enough!!) And yet I'm sure that if people were mode awore of a few things about us, 95% of these losses could be prevented.

From time to time we suffer through moliciousness. Halloween, without fail, finds pranksters attempting in various ways to pry us up. Souvenir hunters, too, frequently steal us for use as paperweights, bookends, or just for the thrill of an unusual memento. The laugh will be on them if they are ever caught, though! Imprisonment or a $250 fine hardly seems worth the thrill they receive from such frolicking.

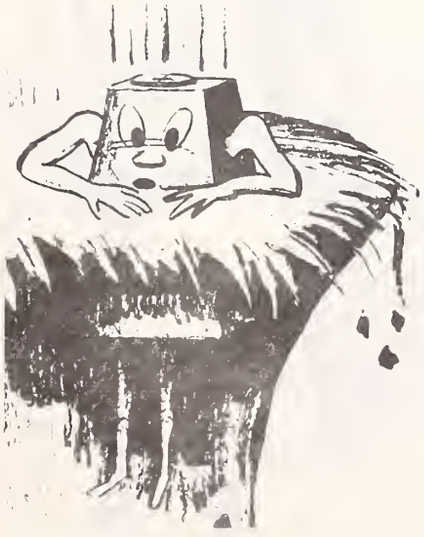
Our biggest enemy, however, is the mon behind the bulldozer or grader. Brother! On more thon one occosion in my lifetime I hove hod to do some fast praying for fear thot I would follow some of my relatives to the grave — an unfortunote victim of o crushed disk! I thonk my lucky stars that the present owner of the property on which I live knows oll obout me, and my volue to surveyors and engineers. He tokes special precautions to see that I stay heolthy, and that no man or machine domages me.

It's because of these well informed, thoughtful people who are careful to watch for us and for our distress signs, thot mony Markers live long, useful lives. Actually, we are supposed to be immortal. But, some of the fomily have died of old oge, erosion or sedimentation because the services of a professionol engineer were not engaged soon enough to save them.

Please, won't you perform a voluable service to your country and community by helping Markers live a normal life span? Engineers, businessmen, housewives, students, — Just about every citizen can help!

Remember these facts!

(1) Never remove a survey marker. Once this is done, the value of it is lost entirely, ond replacement is costly.



(2) If there is construction going on in your orea and you notice a survey mark which appears to be in the way, call it to the attention of the surveyor in charge to insure that he is aware of it.

(3) If you see a survey mork which oppears to be susceptible to damage of any kind, or which seems to be undergoing erosion or other "old-age oilments," flag it by driving stokes neorby ond morking them with red ribbon, cloth, or plastic.

(4) In oll coses, submit o report of your findings to The Director, Coast and Geodetic Survey, U.S. Department of Commerce, Washington 25, D.C.

When you respond to this appeol, you will be performing a tremendous service for your Government. And as for me and the Marker Family, you will be helping to achieve longer and better lives for Markers oll over the World.

Thanks from the entire family!

HELP PRESERVE SURVEY MARKERS

US COMM-CGS-DC PIO 2-62

KNOW THESE MARKERS

BENCH
(Old Type)

BENCH
(New Type)
Two Bench Marks Consolidated

BENCH
(Old Type)

TRAVERSE

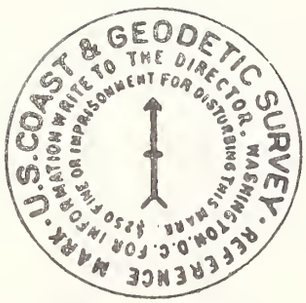
TRIANGULATION

GRAVITY
(Old Type)

GRAVITY
(New Type)

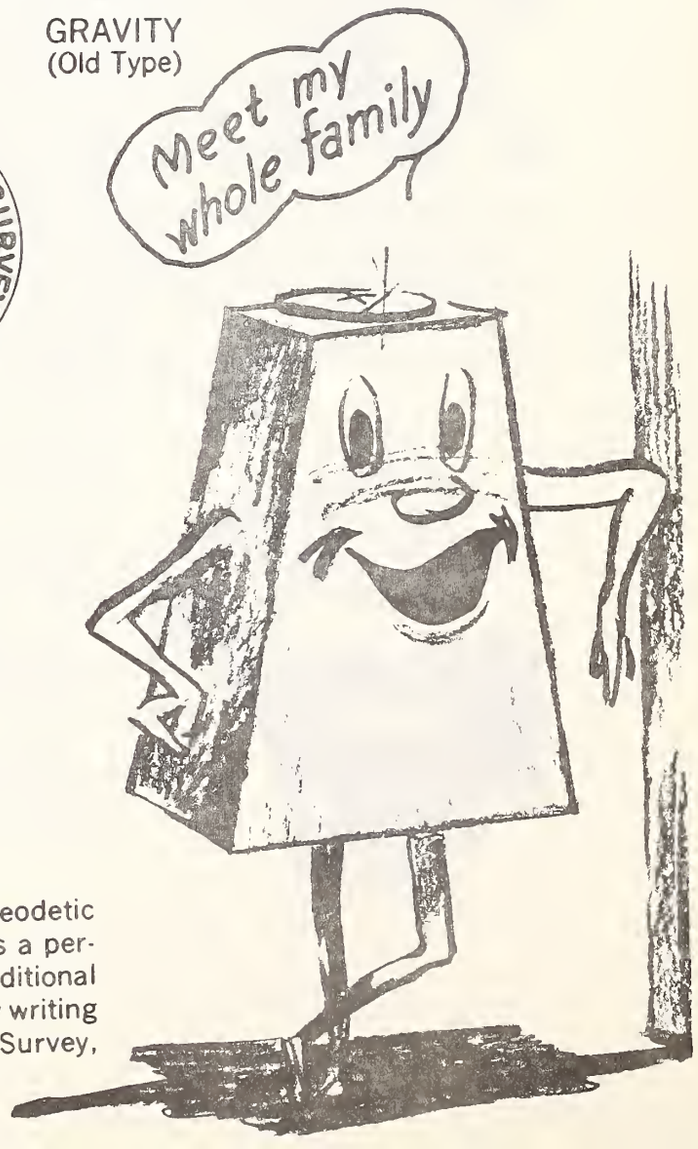
TOPOGRAPHIC

AZIMUTH



REFERENCE

MAGNETIC



FACE LEGENDS

Standard bronze station marks of the Coast and Geodetic Survey that are set in concrete or bedrock to serve as a permanent mark for the particular station it represents. Additional information concerning these marks may be obtained by writing to the Director, United States Coast and Geodetic Survey, Washington 25, D.C.

RELOCATION OF BENCH MARKS

Frequently new construction or repairs to existing structures necessitates the destruction of bench marks, in spite of the fact that every effort has been made to place them where they will be as permanent as possible. This bureau has no funds from which to pay field parties to relocate these marks when they must be moved. If these marks are to be preserved for the use of all engineers and surveyors who may have occasion to use them, we must depend on the cooperation of engineers and others throughout the country for assistance in their preservation. Obviously it is to the best interests of all concerned that bench marks be relocated rather than destroyed.

There has been developed a routine method of handling such cases. If engineers who encounter our marks in the course of construction repair or maintenance operations will cooperate as outlined below, the destruction of useful bench marks will be very much reduced.

As soon as it becomes known that a mark must be moved, a letter should be sent to the Director, United States Coast and Geodetic Survey, Washington 25, D.C., attention Section of Leveling, stating the necessity for moving the mark and giving its designation. The designation consists of the letters and numbers stamped with dies on the disk. It is desirable to furnish a rubbing of the disk as well. (See p. 15) Upon receipt of this information, this office will send out a new disk properly stamped to show it has been reset.

The proper procedure, in most cases, is to establish the new mark in a safe place nearby and transfer the elevation from the old mark to the new one by means of an engineer's level and rod. The levels should be run in deplicate to avoid the possibility of large errors, and all readings should be made to three decimal places in order to preserve the accuracy of the original elevation.

The old mark should not be disturbed until the observation involved in the transfer of elevation have been checked by the observer or the recorder. An assumed elevation for the old mark may be used in the transfer, since we are principally concerned with the difference in elevation between the old mark and the new one established to replace it.

After the new mark has been established and the elevation transferred to it, the old disk should be broken out and returned in a franked mailing sack which will be supplied for the purpose. A complete report on the action taken, including a description of the location in which the new mark is established and a copy of the field notes involved in the transfer of elevation, should also be forwarded to this office in a franked envelope which will be furnished.

The cooperation which individuals and organizations may extend to this bureau in preserving bench marks will be a service, not only to this bureau and other government surveying organizations, but to all who may have occasion to use this marks in the furture.

The above information was taken from the Bulletin
"Control Leveling", from the U.S. Coast & Geodetic Survey
July 22, 1946.

III-31 CONSTRUCTION SURVEYS FOR ROADWAYS

31.00 References

Standard Specifications: Section 5

Field & Office Standards: Sheets 40, 41, 42 and 43

31.01 Re-establishing Centerline

The centerline, or another line as designated on the plans as the base line, from which measurements are to be taken for laying out the work and setting stakes for horizontal and vertical control is one of the first procedures in staking a highway project. It is obvious that any stakes set on the centerline will be destroyed during the construction operations. Centerline need only be temporarily marked for use during staking. During the course of construction the centerline or base line will have to be re-established frequently depending on the nature of the construction under way. Therefore, a sufficient number of control points on the line must be tied in or referenced to fixed objects such as iron pins, hubs and tacks, etc. so the line may be readily re-established at any time during construction or after completion of the project.

The plans should be checked and notebooks prepared before any staking is begun and at least one set of plans is to be available for use of the staking party at all times. Occasionally errors in the plans or the original field location are found by the staking party. Notations of these errors are to be made on the field plans as well as in the notebooks. All of the curve data shown on the plans should be checked and transferred into the transit notes before staking is begun.

A transit book is to be prepared in advance of staking from information on the plans. Plenty of space should be left between entries to allow for additional information that is unanticipated and to prevent crowded notes. Transit notes are unique in their construction since the stations are listed up the page consecutively from the beginning station onward to the ending station because this is the way the surveyor views the centerline and it is more convenient to describe details as he sees them. Similarly, the sketches on the right hand page of the transit notes will begin at the bottom of the page and progress upwards to the top of the page. The stationing of all transit points shown on the plans should be entered in the transit notes at the proper place according to the station numbers. Reference points or ties should be entered opposite the corresponding station number on the right hand page. The

appropriate station number of piers, bents, and end bents of each structure shown on the plans should be entered into the field book so the centerline location for these structure points may be established as the centerline is run.

The right-of-way lines on each side of centerline and their distance from centerline should be shown on the right hand page of the transit notes.

A. Staking Centerline

Accepted survey practice is to be used when staking centerline or performing other survey functions. Care should be taken to assure that the chain is in a horizontal plain. Too frequently the alignment of the tape is set very precisely, whereas the vertical control is established by eye only instead of using a hand level. After locating the beginning of the project from the nearest established transit point, each station should be set from there on. Half stations or other plusses necessary for right-of-way breaks, curves, topography, or for the centerline of each structure should also be set at this time. The staking party should be organized for the maximum efficiency by locating transit points shown on the plans ahead of centerline staking or arranging to set these points concurrently with centerline staking where efficiency can be gained.

Errors in chaining may occur or be discovered as the centerline is being run and staked. Small chaining errors should be corrected at the first POT or at the first PT after the error is found. Errors resulting in an equation greater than one foot should be recorded. When very large errors in chaining occur, an equation should be made, as near the point of the error as possible.

An equation is a survey point that is used to adjust errors in the measured distances and has two station numbers. One of the station numbers is used as a reference stationing for all measurements from the point back towards the beginning of the project. The other station number is used as a reference station from which all measurements from that point ahead are taken. An example of an equation is Station 201+50.0(back) equals 201+28.3(ahead). This equation is called a plus equation because the length of the line has been increased and in this instance the increase is 21.7 feet.

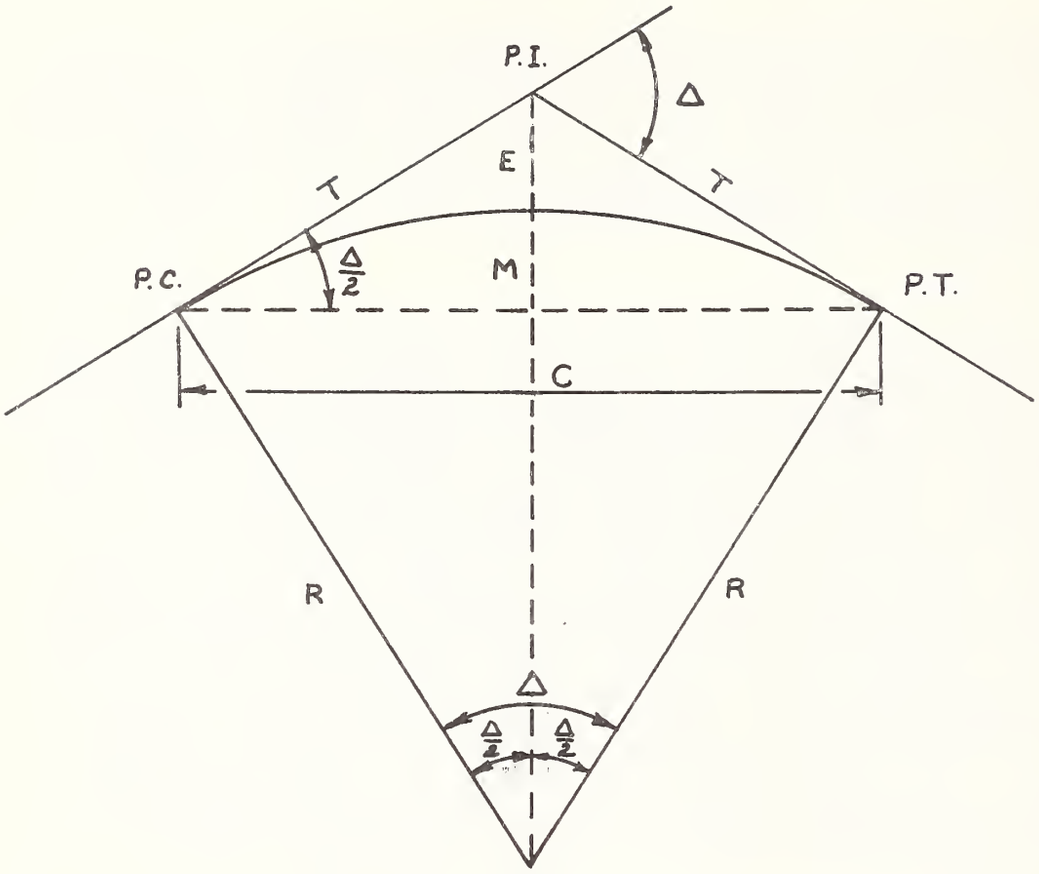
The engineer in charge of the survey team re-establishing centerline should use planning and foresight in locating and referencing points. Transit points

should be set so they may be re-established from other transit points along the survey line, thus, if transit points are lost they may be re-established by extending tangents from other established points or by forming an intersection of known tangents.

B. Simple Curve

Specific information on the computation of curve data can be found in a number of engineering handbooks, to which the engineer-surveyor is referred, for thorough coverage. Highway curve data is computed from the arc definition which states that a one degree curve is the curve of a radius such that one degree of central angle subtends an arc of 100 feet in length. The value of various curve functions vary inversely with the degree of curve for any given central angle, for instance, the radius varies inversely with the degree of curve such that the radius of a one degree curve is set at 5730 feet; therefore, the radius of a two degree curve is one-half of 5730 feet, the radius of a three degree curve is one-third of 5730, and so on. The following tabulation, Figure III-1, lists the basic circular curve formulas for use in computing simple curve functions.

Curves are usually staked for each station and each half-station, except for the odd distance from the PC or PT to the first station on a curve. The length of curve is computed along the arc, but the chain is stretched along a chord between points on the curve, therefore, a correction may be necessary depending on the sharpness or degree of curvature. However, chord corrections may be disregarded for 100 foot chords used for curves up to 6 degrees; 50 foot chords for curves up to 12 degrees; 25 foot chords for curves up to 24 degrees, and 10 foot chords for curves over 24 degrees.



D = Degree of Curvature in Degrees

L_C = Length of Curve

R = Radius of Curve

T = Tangent Distance from P.C. to P.I. and P.I. to P.T.

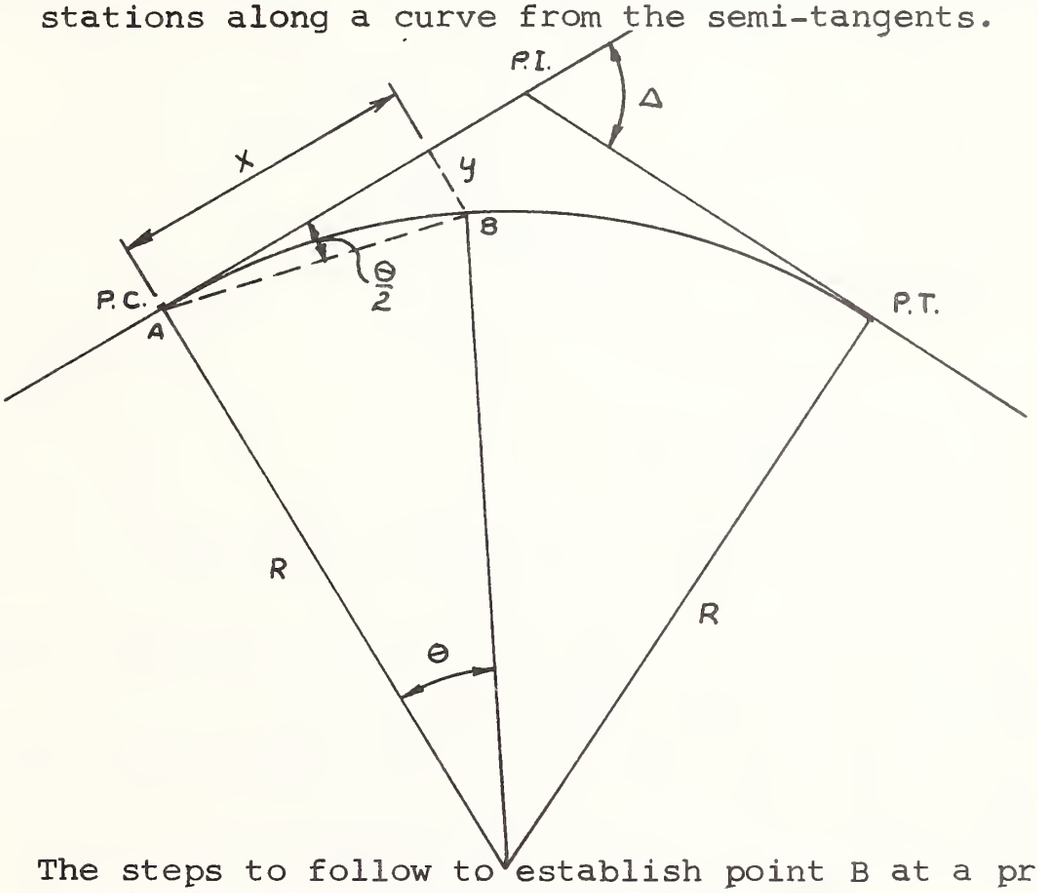
$$D = \frac{5729.5780}{R} \qquad T = R \tan \frac{\Delta}{2} \qquad L_C = \frac{100\,\Delta}{D}$$

$$M = R(1-\cos \tfrac{1}{2}\Delta) \qquad E = T \tan \frac{\Delta}{4} \qquad C = 2\,R \sin \frac{\Delta}{2} \text{ or}$$

$$C = 2\,T \cos \frac{\Delta}{2} \quad \text{or} \quad \text{Chord Length (for any arc Length = S)} = 2\,R \sin \left[\frac{(S)\,(D)}{(2)\,\,(100)}\right]$$

Fig. III-1

On many surveys the entire curve cannot be seen from the PC or the PT. Whereby intermediate setups or alternate methods of setting each centerline stake along the curve may be necessary. Figure III-2 is an example of the tangent offset method for establishing centerline stations along a curve from the semi-tangents.



The steps to follow to establish point B at a pre-determined station on the curve are as follows:

1. Subtract station at P.C. from station at B to determine arc length AB.

2. Determine deflection angle e/2 from curve data for the point in question, s=Arc length AB

$$\frac{e}{2} = \frac{(S)\ (D)}{100\ (2)} \qquad \text{or} \qquad \frac{e}{2} = \frac{S}{L_c} \times \frac{\Delta}{2}$$

3. Determine chord length AB from:
chord length (AB) = $2\ R\ \text{Sin}\ (\frac{e}{2})$.

4. $X = AB\,\text{Cos}\ e/2$

$Y = AB\,\text{Sin}\ e/2$

Fig. III-2

EXAMPLE:

P.C. Station 15+24.60

$D = 3^{\circ}\ 42'$

$R = 1548.5346$ ft.

$\Delta = 27^{\circ}\ 24'$

$L_c = 740.540$ ft.

To set a point at station 17+00

1. Arc length = (17+00) -(15+24.60) = 175.40 Ft.

2. Deflection angle $\frac{e}{2} = \frac{(175.4)\ (3.70)}{100\ (2)} = 3.2449^{\rho} = 3^{\circ}\ 14.7'$

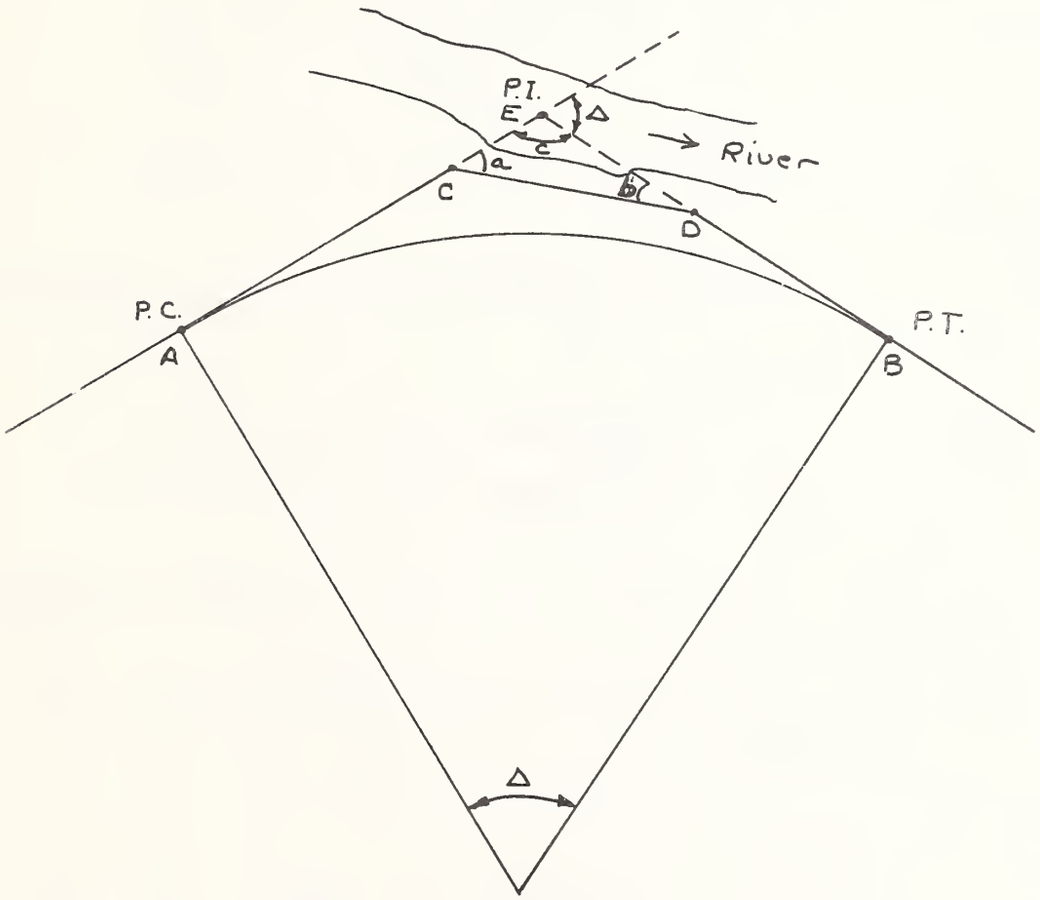
3. Chord Length AB = (2) (1548.5346) Sin(3.2449) = 175.3118

4. X = (175.3118) (Cos 3° 14.7') = 175.03'

   Y = (175.3118) (Sin 3° 14.7') = 9.92'

Fig. III-2a

In some cases the Point of Intersection(P.I.) of the tangents is inaccessible and therefore, cannot be used as a control point. In order to determine Δ and other data necessary for locating a curve the following procedure is suggested.



1. Locate points C and D on their respective tangents at any convenient position.

2. Measure angle a, distance CD and angle b.

3. Then $\Delta = a + b$ & $c = 180 - \Delta$

4. Solve for CE and ED by law of sines.

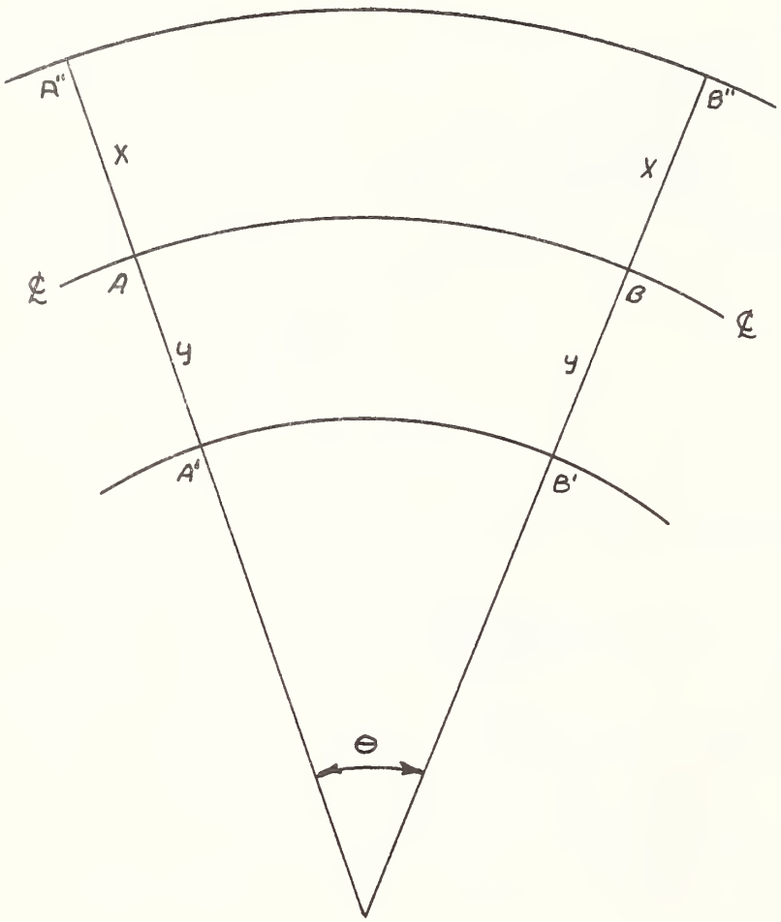
$$ED = \frac{\sin a}{\sin c}(CD) \quad \& \quad CE = \frac{\text{Sin } b}{\text{Sin } c}(CD)$$

5. Once the tangent lengths (T) of the curve are established from the curve data, the P.C. can be set by measuring back from point C a distance equal to T - CE.

6. The P.T. can be set by measuring ahead from point D a distance equal to T - ED.

Fig. III-3

It is often necessary to locate outer or inner concentric curves for various reasons and in order to maintain accurate stationing as compared to the centerline, the outer or inner arcs must be adjusted to correspond to the distances laid out on centerline. See Fig. III-4



X = distance from centerline to outer arc measured perpendicular to the centerline.

Y = distance from centerline to inner arc measured perpendicular to centerline.

R = Radius of curve

D = Degree of curvature

Δ = Total central angle (degrees)

L_C = Length of curve on centerline

$A''B'' = AB + [(X)(.017453)(\theta)]$

$A'B' = AB - [(Y)(.017453)(\theta)]$

θ = Central angle for Arc AB

Note that A'B' is less than AB and A"B" is greater than AB.

Example: Given: X = 50 ft. Y = 40 ft. $\Delta = 30^{\circ}\ 30'$
$D = 6^{\circ}\ 00'$ AB = 50 ft.
Find: A'B' & A" B"

Fig. III-4

1. $L_c = 100 \frac{\Delta}{D} = \frac{30.5^\circ}{6} (100) = 508.33$ ft.

2. Central angle for 50 ft. arc on centerline = $\frac{D}{2} = 3^\circ = \theta$

   or Central angle for any length arc (s) on centerline = $\frac{S}{L_c} \times (\Delta) = \frac{50}{508.33} \times (30.5^\circ) = 3^\circ = \theta$

3. A"B" = 50 + (50) (.017453) (3) = 52.62 ft.

   A'B" = 50 - (40) (.017453) (3) = 47.91 ft.

Alternate Solution for Concentric Curves

R = Radius on ℄

R'= Radius of inner concentric = R - Y

R"= Radius of outer concentric = R + X

Example: Given X = 50' Y = 40' R = 954.93 AB = 50'

1. R' = 954.93 - 40 = 914.93

   R" = 954.93 + 50 = 1004.93

2. $A'B' = \frac{R'}{R} \times AB = \frac{914.93}{954.93} \times 50 = 47.91'$

   $A"B" = \frac{R"}{R} \times AB = \frac{1004.93}{954.93} \times 50 = 52.62'$

For more complete information on circular curves refer to the book "Route Location and Design" by Thomas F. Hickerson.

Fig. III-4a

C. Spiral Transition Curves

Spiral transitions are provided at each end of the circular curve to provide a gradual transition from the tangent to the full super-elevated curve. A spiral transition has the property of an ever-increasing curvature starting with 0 degrees and ending with the same degree of curvature as that of the horizontal curve. Information on the spiral curve and super-elevation transitions will be found on the plans. For complete information on the computation of spiral curve transitions refer to the book "Transition Curves for Highways" by Joseph Barnett of the BPR, or "Route Location and Design" by Thomas F. Hickerson. See Figure III-5a, b, c, for spiral curve offset computations.

31.02 Bench Marks and Leveling

Bench marks should always be established outside of the construction limits. Bench marks that have been established on a location survey and are in the way of construction should be re-established outside the construction limits. Bench marks should be set no more than 1,000 feet apart using long iron pins, bars, pipes, concrete monuments, bridge abuttments, or some similar control for permanency. The height of fill and depth of cut should be taken into consideration when establishing bench marks so that locations are convenient for future surveys performed before, during, and after construction of the roadbed. Strategic locations for bench marks are generally as follows, but the engineer should take into consideration the terrain of the country and the type of work underway.

1. Each end of large structures.

2. Points of change from cuts to fills.

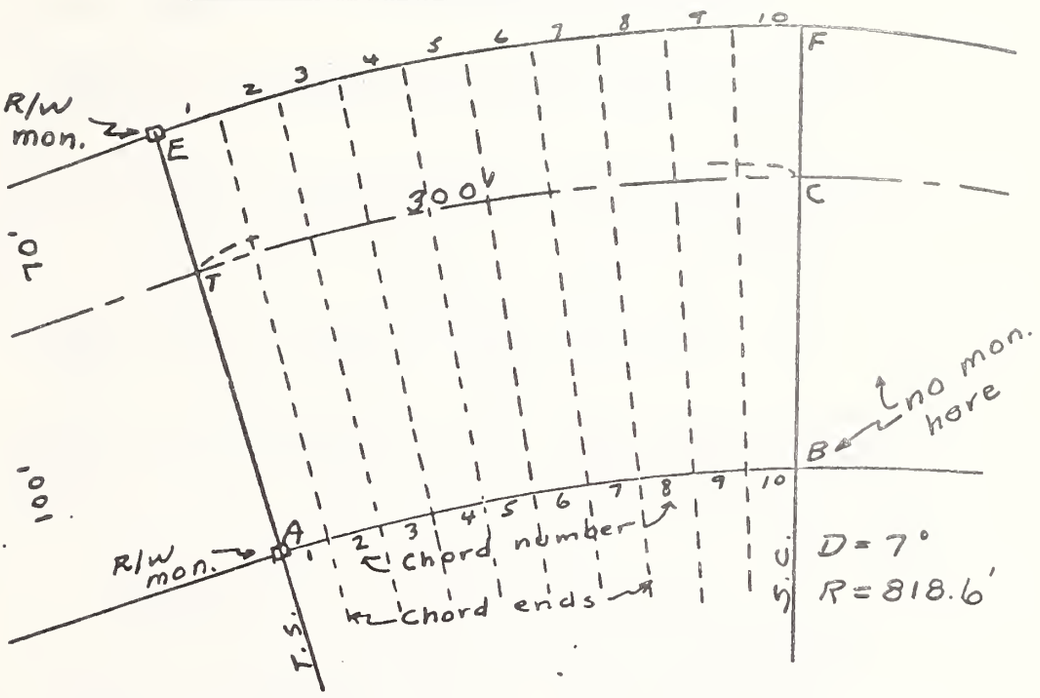
3. Mid-height of a side hill cross section.

4. 25 foot differences in elevation on rolling terrain.

5. Not to exceed 1,000 foot intervals in level country.

Bench marks established either by the location survey or by the construction survey team should be tied in with the United States Geological Survey Department or the U.S. Coast and Geodetic Survey when possible. If these survey data monuments have not been placed near enough to the construction projects, the State's own level circuit should be run and contain an accuracy of 1 in 5000. This level circuit should be checked and the maximum error should be no greater than 0.05 times the square root of one mile, for the desired one in five thousand accuracy.

PARALLEL SPIRAL CURVES



The TOTAL CHAINING CORRECTION for an offset spiral is equal to 1/2 the total chaining correction for an offset line the same distance from a simple curve with the same degree of curvature and length as the spiral.

Formula for determining AB & EF

R = radius, in feet, of circular curve
L = length of spiral on C L
P = distance CL to parallel spiral (R/W above)
C = correction applied to CL spiral to obtain length of parallel spiral

$$C = 0.5\left(\frac{P}{R} \times L\right)$$

T = correction in CL length for end of any chord from TS (or ST.).
M = correction for each chord length
N = chord number as decimal of total (Ch. 2 = 0.2)

$$T = N^2 \times C. \quad M = T_2 - T_1 \; ; \; T_5 - T_4 \; ; \; T_9 - T_8 \; ; \text{ etc.}$$

Any chord number divided by two, and squared, times the total correction will give the chaining correction from the T.S. (or the S.T.) through the chord used.

CSN-05A

Fig. III-5a

COMPUTATION EXAMPLES

See CSN-05A

$C = 0.5 \left(\frac{P}{R} \times L\right)$ P = 70'; R = 818.6'; L = 300'

$C = 0.5 \left(\frac{70.0}{818.6} \times 300\right) = 0.5 \times 0.0855 \times 300 = 12.83'$

Thus: TC = 300'; EF = 312.83'

P = 100'; R = 818.6'; L = 300'

$C = 0.5 \left(\frac{100.0}{818.6} \times 300\right) = 0.5 \times 0.12216 \times 300 = 18.32'$

Thus: TC = 300'; AB = 281.68'

Determination of chord lengths: "Table X"

Using 70' R/W $T = N^2 \times C$

Chord				T	
1	$.1^2$	x	12.83	= 0.128'	T = total correction
2	$.2^2$	x	12.83	= 0.513'	from T.S. to end of
3	$.3^2$	x	12.83	= 1.155'	any chord.
4	$.4^2$	x	12.83	= 2.053'	
5	$.5^2$	x	12.83	= 3.208'	e.g. - Total correc-
6	$.6^2$	x	12.83	= 4.619'	tion from E to end
7	$.7^2$	x	12.83	= 6.287'	Chord 5 = 3.2'; from
8	$.8^2$	x	12.83	= 8.211'	E to end Chord 9 =
9	$.9^2$	x	12.83	= 10.392'	10.4' plus (9x30)
10	1.0^2	x	12.83	= 12.830'	270 = 280.4'

To obtain correction for each chord: subtract. "Table Y"

$M_1 = 0.13$
$M_2 = 0.51-0.13 = 0.38$
$M_3 = 1.16-0.51 = 0.65$
$M_4 = 2.05-1.15 = 0.90$
$M_5 = 3.21-2.05 = 1.16$
$M_6 = 4.62-3.21 = 1.41$
$M_7 = 6.29-4.62 = 1.67$
$M_8 = 8.21-6.29 = 1.92$
$M_9 = 10.39-8.21 = 2.18$
$M_{10} = 12.83-10.39 = 2.44$

(See following page)

CSN-05B

Fig. III-5b

Computation Examples (Continued)

Chord lengths on 70' R/W line: (Corrections Table Y)
Chord 1 on CL is 30'; all others are the same

Chord 1 : 30.00 + 0.13 = 30.13 5 = 31.16 8 = 31.92
Chord 2 : 30.00 + 0.38 = 30.38 6 = 31.41 9 = 32.18
Chord 3 : 30.00 + 0.65 = 30.65 7 = 31.67 10 = 32.44
Chord 4 : 30.00 + 0.90 = 30.90

Total distance from E to end of chords:

1 - 30.00 + 0.13 = 30.13 5 - 153.21 8 - 248.21
2 - 60.00 + 0.51 = 60.51 6 - 184.62 9 - 280.39
3 - 90.00 + 1.16 = 91.16 7 - 216.29 10 - 312.83
4 - 120.00 + 2.05 = 122.05

(CL chords plus corrections in Table X)

To obtain chaining corrections for the 100 ft R/W Line, prepare data like in Table X, using C = 18.32. Then proceed in same manner as for 70' line, except corrections are to be subtracted.

Curve deflections at end of each chord on the parallel line are the same as for end of each chord on centerline.

To run a line perpendicular to the centerline spiral at any point, take twice the deflection (Z°) for that point, sight on T.S. (or S.T.), turn

$90^{\circ} + Z^{\circ}$ for the outside of the spiral
$90^{\circ} - Z^{\circ}$ for the inside of the spiral.

The above procedure seems long and complicated. However, it is purposely that way for the beginner. Practice will develop short cuts.

See Table VI, Page 188, "TRANSITION CURVES FOR HIGHWAYS", by Joseph Barnett; "ROUTE SURVEYS & DESIGN" by Thomas F. Hickerson, A.S.C.E. (McGraw-Hill)

CSN-05C

Fig. III-5c

When errors occur in bench mark elevations, these should be corrected in a manner that will not affect the elevations of succeeding bench marks. If a minor error were to change the elevation of succeeding bench marks an equation in the elvations should be set up at a point where the error is noted. A minor adjustment in grade may be necessary in this event. Major errors in bench mark elevations should be referred immediately to the Division Construction Supervisor who will work out the details for correction. It is not advisable to accumulate small variations found in elevations of the original bench marks. To minimize the accumulation of small errors, the back-site and fore-site distances should be kept approximately equal. Bench marks should be used for turning points wherever possible. The level rods should be waved slightly to obtain the lowest reading. Plant the level firmly, level it and be sure it remains level when carefully reading the rod.

Each bench mark is to be described in the level book giving elevation, station and distance to the survey line, together with an accurate description of the object on which the bench mark is established. Level notes can be easily arranged in a uniform, neat, manner yet mistakes can sneak in. To insure accurate results and to avoid errors the notekeeper must continually check turning points, bench marks, rod readings, and computations.

31.03 Staking Right-of-Way

The right-of-way plans and a transcript of each right-of-way parcel must be used to insure that right-of-way, as shown on the plans, is staked as legally described and intended. Should assistance be necessary, the Division Right-of-Way Agent may be contacted to help interpret the information. Stake the right-of-way line on both sides of the construction centerline. The distance between stakes will vary according to terrain but intervals of 100 feet are preferred on level ground and 50 feet on curves. Stakes should be set at all corners and at changes in width or direction. Property owners use these stakes to reset fences, determine property lines, etc. Therefore, accuracy is important. Mark the front side of the stake with "R/W", and the distance from centerline. Print the stationing on the back of the stake.

31.04 Clearing and Grubbing Stakes

The Standard Specifications propose three methods of measuring, clearing and grubbing units. A lump sum basis, area basis and linear basis. Therefore, staking must be compatible with the method of measurement. Clearing and grubbing limits are always established within the right-of-way with due allowance made for movement of contractors equipment. Sharp breaks in the width of the clearing line may be avoided by adjusting the clearing stakes. Clearing lines on the inside of curves and at intersections should be given special attention to provide adequate sight distance when the right-of-way width will permit this.

Distances will be measured to the nearest foot and stakes or laths placed to clearly distinguish the intended limits. Stakes or lath should be spaced approximately 100 feet apart, as a general rule, and placed so one lath can be seen from the next one, etc., but the spacing will be dependent upon terrain and denseness of the foliage. When clearing areas of heavy timber, clearing stakes should be set in a somewhat irregular alignment thus when clearing is completed a more natural appearance will result. Stakes or lath properly set are marked "clear" and usually flagged.

The stakout notes will show stationing, distance left and right, date and names of persons making the stakeout. The areas that have been staked should be reviewed by the contractor so that he is aware of the staking procedure, the general areas to be cleared or grubbed and can raise any questions before work begins.

A limited number of trees and shrubs may be retained to blend into the right-of-way and adjacent terrain, providing screens for unsightly areas, and enhancing the natural appearance. Mark the trees to be saved with a red cloth or other suitable identification and inform the contractor that trees so marked are not to be cut. Trees and shrubs to be retained should be only sound, vigorous, of a desirable species, and not create future maintenance problems.

31.05 Slope Staking

Slope staking and measurement of earthwork quantities is an area where more disputes with contractors arise than any other phase of highway work. Naturally, cross sectioning and setting slope stakes by competent, experienced personnel, properly equipped and instructed is a most desirable goal. However, the seasonal workload requires hiring inexperienced personnel and other factors occasionally prohibit all survey personnel from being the ultimate in competency and experience. Therefore, it behooves the Project Manager to do careful planning and sufficient preliminary work in ample time to permit cross-sectioning work to follow in an orderly manner. Construction cross-sections should be taken wide enough to include all possible areas that might be disturbed. This will help eliminate back tracking and extending cross sections when later construction activities demand wider areas.

All such preliminary work as centerline staking, establishing bench marks and offset lines and preparing a grade book or a system of grade computation sheets will greatly aid the cross sectioning and slope staking party. When clearing and grubbing work is necessary prior to cross sectioning and slope staking, it will be wise to anticipate the most probable location of slope stakes. Cross sectioning will usually be performed when slope staking but after clearing and grubbing is completed. Sections will be taken at all breaks in the centerline profile and at all other breaks in topography within the roadway prism and at cut to fill transitions.

The normal cross-section interval will be 50 feet, however, in flat, low terrain 100 foot intervals may be used; whereas, in rugged or mountainous terrain 25 foot intervals may become necessary. Other cross-sections must, of course, be taken at odd stations where significant changes in elevation are noted. Extend the cross-sections beyond construction limits a minimum of ten feet, but in areas where overbreak or slides are anticipated the cross sections should be extended further.

Construction volume computations may change significantly from the plan quantities unless cross-sections are taken on a line truly perpendicular to the centerline on tangents and to radius lines on curves. Right angle prisms may be used to determine the perpendicular line on generally level terrain, but it may be necessary in rough or heavily timbered terrain to use a transit for right angles. The instrument height is to be recorded to the nearest 0.01 foot and rod readings taken to the nearest 0.1 of a foot from a rod held vertically. In very rugged terrain it may be necessary to run a series of off-set lines parallel to the construction centerline before slope staking and cross sectioning is done in order to maintain right angles and to provide another line of elevation points.

An allowance should also be made for earthwork volumes around curves by decreasing the spacing of cross-sections. This procedure will help compensate for inaccuracy of the average end area method (a specification requirement) of computing earthwork quantities around curves. When encountering horizontal curves the cross-section interval should be as follows: For curves less than a 5,000 foot horizontal radius, use 50 foot intervals; 300 foot radius or less, 25 foot intervals; and for 100 foot or less, 10 foot intervals. Sections should always be taken at the P.C., midpoint and P.T. Use 50 foot intervals on vertical curves when the mid-ordinate between the curve and the chord varies 0.2 foot or more between stations.

As the depth of cut increases and virgin terrain is encountered, it is becoming a common practice in highway back-slope design to build compound slopes or slopes with benches or breaks in the back-slope. The staking practices now in existence will give generally satisfactory results with only minor changes. It is suggested that only sufficient reference to cut depth be given to allow excavation down to the bench break then re-establish another reference stake at or near the first bench or break to allow excavation down to the next bench, etc. This method of staking insures that benches or breaks will be constructed correctly and has the advantage of simplicity. However, any other method that will provide proper slopes and place benches of the designed width in the correct location, will be satisfactory.

Cut and fill stakes should be marked with the stationing, depth of cut or fill, the slope and distance to the hinge point (shoulder or ditch bottom).

When cross-sectioning steep slopes, efficiency and speed can be aided by using reference hubs wherever possible. Elevations that are above the height of the rod, or above the height of the instrument can be marked on the reference hub to be "picked-up" on another set of cross-sections. A reference line may also be used. The zero end of the tape should be held on centerline in most cases and the cross-sections taken right and left of construction centerline and extending to the right-of-way line or beyond the construction limits or construction permit. A prismoidal correction is rarely used but may be required on the inside of circular ramps to correct earthwork computations because of the extremely short radius curves; the main line sections should then be extended or a supplemental base line used to cover these locations. Notes for staking the grade in ramps or interchange areas should be made up ahead of time and should be sufficiently accurate to allow ready staking, but not so precise that weeks will be taken to make these notes.

31.06 Staking Borrow Pits

Modern roadway construction is making more frequent use of borrow material to maintain a more uniform grade line and to construct interchange ramp areas in locations where roadway excavation material is not readily available. One of the primary considerations in removing material from a borrow site is determining how much material has been removed for roadway construction and where it was placed. Other considerations involving borrow sites are: topsoil removal and replacement, proper drainage and appearance after the borrow material has been removed. Clear definition of the borrow limits around the perimeter of the site are necessary in order to comply with the intent of the plan description and the wishes of the landowner as he has indicated on the agreement or permit. Borrow areas should be screened from the traveling public by the natural terrain or a row of trees. Borrow sites that are not screened should have their side slopes blended with the natural rolling groundline to provide a neat and pleasing appearance. For complete description of reclamation requirements refer to Section II-21.

The level datum for borrow sites is to be tied in with the road way bench marks where possible. Where borrow pits are located adjacent to the roadway, the roadway cross-sections may be extended for complete coverage of the borrow site. Where it is not practical to tie the borrow site elevations in with the roadway level datum at least two bench marks should be established outside the construction operations and referenced to an assumed elevation. The borrow site notes should contain a sketch of the borrow location including fences, base line stationing, witnesses, references, bench marks, buildings, borrow limits, north arrow, a description of the section

township, range and other pertinent information that would allow another person to re-establish or carry on the work.

Topsoil is to be removed to the required depth and replaced after the borrow material has been excavated and the pit neatly dressed. The topsoil quantities are to be kept separate from other excavated materials. This may require cross-sectioning and computation before the topsoil material is removed; after the topsoil material is removed; and after all the borrow material has been removed. Topsoil quantities thus arrived at will preclude the claims for increased quantities which can often be exaggerated by the contractor when no firm quantities or measurement thereof exists.

Two methods of staking a borrow site may be found in Figure III-6. Borrow pit cross-section notes are similar to other survey notes in that the date, weather information, and members of the crew are to be recorded for each day. These notes should be neat and well kept. Figures that are in error should be crossed out and the correct figure written above. Do not erase.

31.07 Finish Grade Stakes

Line and grade control stakes will be set when the rough grading is sufficiently complete to allow finishing operations. Job conditions and the contractors intended operation are factors that will determine the most economical method of establishing the required line and grade. It is generally helpful, at the contractor's request, to place lath with cut and fill markings at reasonable intervals to allow the contractor a more firm indication of the need for finishing prior to setting of blue tops. However, it is the contractors responsibility to complete rough grading of the roadway to within a half a foot or so of the true grade before he requests blue tops. It will help contractor-engineer relations to set rough stakes or laths, but this practice should not take precedence over other pressing work such as setting final blue tops where they are required in other locations. It is well to discuss with the contractor how and when rough-grading stakes will be established so that both the engineers schedule and the contractors operation will compliment each other and thereby minimize delays.

Finish grade stakes "blue tops" are to be set at 50 foot intervals along the shoulder line, quarterline and centerline on tangent sections or as needed to provide the proper construction of the roadway section. It may be necessary to set blue tops at 25 foot intervals around curves depending upon the radius and where transitions or changes in super elevations occur. The top of the stake is to be driven to the proper elevation and marked with crayon or paint to indicate that its top is at grade.

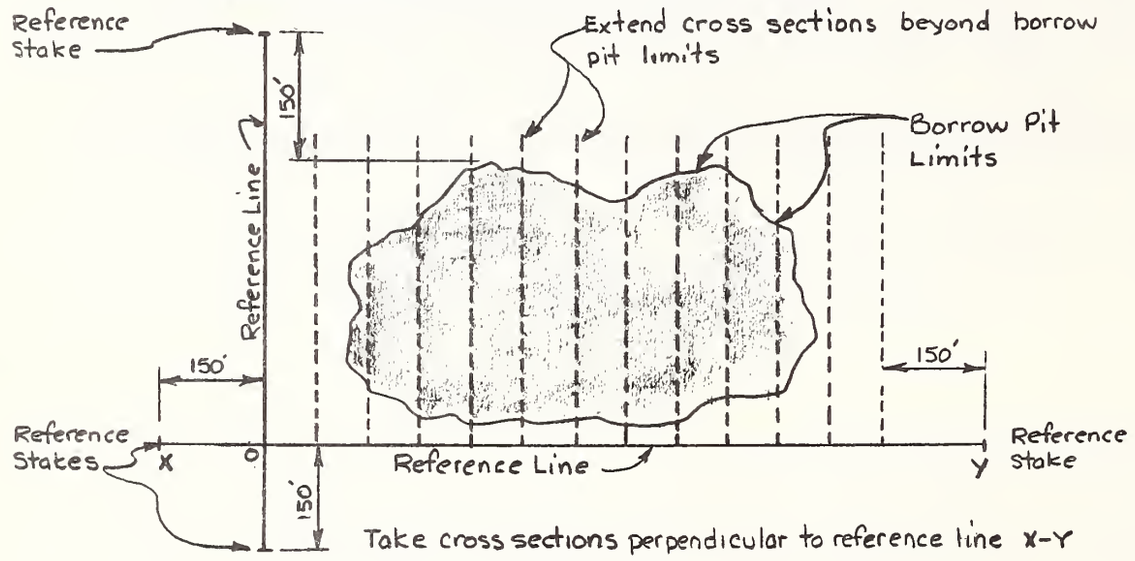
Care should be exercised to provide a smooth transition where the roadway grade meets an existing bridge or other changes in elevation occur. Changes in elevation should be drawn out over a long distance to make the transition as gentle as possible.

Grade and line for concrete paving are usually established along the shoulder line by a series of stakes set at 25 foot intervals, to approximately 0.01 foot accuracy and offset a uniform distance away from construction machinery. The contractor may then place iron stakes to support a piano wire at a uniform height above the true grade and to the same degree of accuracy as the original grade control was established. When the piano wire has been properly set and checked, small deviations may be observed by sighting along the wire. Corrections must be made, when needed, before accepting the position of the wire as accurate.

BORROW SITE CROSS SECTIONING

Take cross sections at each intersection of lines forming a 25' grid network. Use other points, as necessary, to show the true ground surface. Distances or dimensions shown below are for the surveyors guidance. Use judgement to fit the survey to the natural terrain.

1. Typical Borrow Excavation Site



2. Borrow From Old Embankments or Long Rows of Material

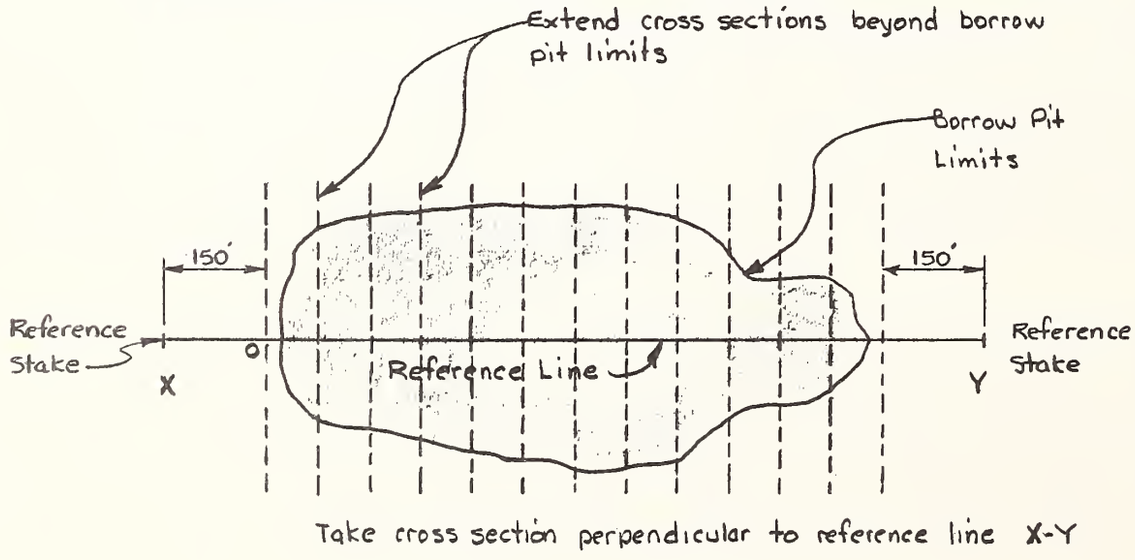


Figure III-6

III-32 CONSTRUCTION SURVEYS FOR SMALL DRAINAGE FACILITIES

32.00 References

Standard Specifications: Sections 52 through 77

32.01 General

The proposed flow line elevation for outlet ditches, sewers, channel changes, culverts and other drainage facilities are shown on the plans. However, during the time interval from plan completion to contract award, mother nature or men may have caused changes in the existing drainage course. Therefore, culverts and other drinage facilities, as planned, may not be in exactly the correct position. It is a good idea to make a thorough review of the existing drainage course compared with the location shown on the plans. Profiles of existing drainage are to be taken if there is any doubt whatsoever.

Existing culvert or storm sewer flow lines through adjacent highways, railways, or other facilities may effectively control the flow of water through the intended construction zones. Drainage facilities through the new road bed may require adjustment to conform to in place drainage facilities. ALL DRAINAGE MUST HAVE AN OUTLET. Good drainage and good design of drainage facilities is truly a science, but common sense and good judgment are an absolute necessity if water is to be properly drained without causing property damage, floods or undue erosion.

32.02 Pipe Culverts

Almost every culvert must be staked and installed before grading can begin and the staked length must be known so the contractor can order a reasonably accurate quantity. Although the location, type, size, length and elevation of flow line are shown on the plans, all conditions affecting these requirements should be checked before the culvert is staked. Any major change must be authorized before installation. Culverts should be staked and the staking information made sufficiently clear so there will be no error on the part of the contractor or inspector due to misunderstanding. Skew angles, as shown on the plans, should correspond with field conditions, but if they do not, corrections must be made so the installation will conform with field conditions.

The staked length of culvert pipe must fit the slope and generally, should conform to a multiple of the commercial length available for that size of pipe. A hub and tack is to be set at each end of the pipe centerline a sufficient distance beyond the construction limits to prevent their destruction. A guard stake placed over each hub and tack should show the cut or fill to flow line and the distance offset from the end of the culvert. Other information relative to the length, type and size of pipe needed for instllation, may also be shown on the guard stakes. After the

stakes have been set, a check should be made of the total fall and direction of flow, a gradient of 0.3% is generally the minimum grade that will carry sediment. The culvert flow line elevation (invert) should be staked about 0.2 feet lower than the flow line elevation of the inlet and outlet channels to help minimize piping, obtain a more solid bedding and provide more of an opening for small flows.

32.03 Concrete Box Culverts (Fig. III-7)

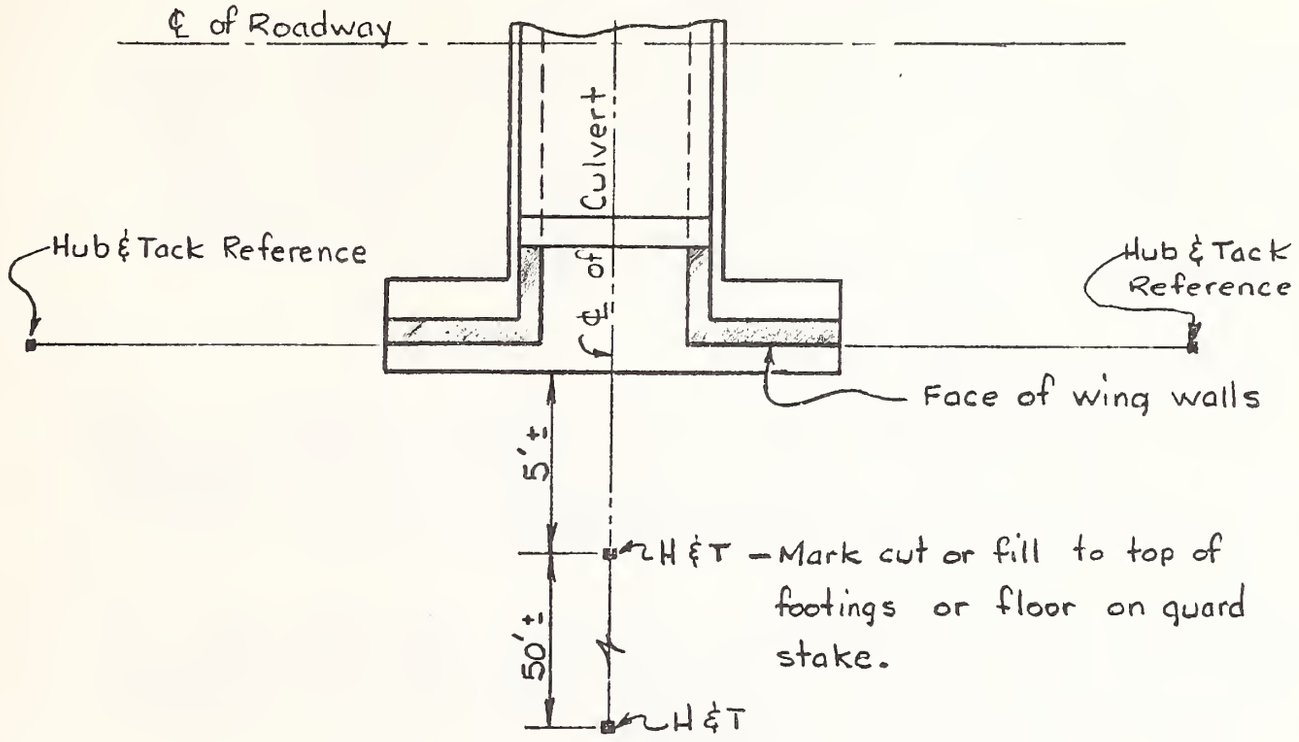
Although the use of concrete box culverts is quite limited, when a concrete box culvert is encountered, the following guides should be followed. The plans of concrete box culvert installation should be thoroughly studied and checked before any firm stakeout is made. The initial staking of box culverts is made on reference lines set parallel to the centerline of the structure. Hub and tack references placed sufficiently outside of the construction zone should be set at each end of the centerline and at convenient locations on the other reference lines run. The need for reference lines will be up to the judgment of the Project Manager but is based primarily on the width, length and location of the box culvert. The culvert centerline and a reference line to the face of wingwalls should be staked. Set finish grade stakes after excavation to the footing elevation. After the footing is in, the remainder of the structure layout can be easily marked by the contractor and checked by the inspector providing that a number of reference elevations are available and alignment is provided. The staking method should be carefully explained to the contractor and the inspector by the Project Manager. It is not adequate for the Project Manager to assume that his inspector has all the necessary knowledge and skill to properly inspect an installation. For example, planned elevations referred to certain portions of the structure may be ambiguous, since the planned elevation or the bottom of the footing may change because of subsurface or construction conditions. In such instances confusion and mistakes may be avoided if the reference stakes are simply marked for the elevation of the reference itself and the meaning of these references explained to the inspector.

32.04 Dikes and Ditch Blocks

Dikes will usually follow the roadway shoulder line to curving or parallel alignments, therefore, stakes marking the extremities of the dikes are usually satisfactory. An adequate number of stakes should be set to delineate all of the features of the dikes and to allow an accurate computation of the earthwork volumes involved.

STAKING METHOD FOR BOX CULVERTS

Culvert at 90° angle to Roadway ℄


℄ of Roadway
℄ of Culvert
Hub & Tack Reference
Hub & Tack Reference
Face of wing walls
5'+
H & T – Mark cut or fill to top of footings or floor on guard stake.
50'+
H & T

Culvert at less than 90° angle to Roadway ℄

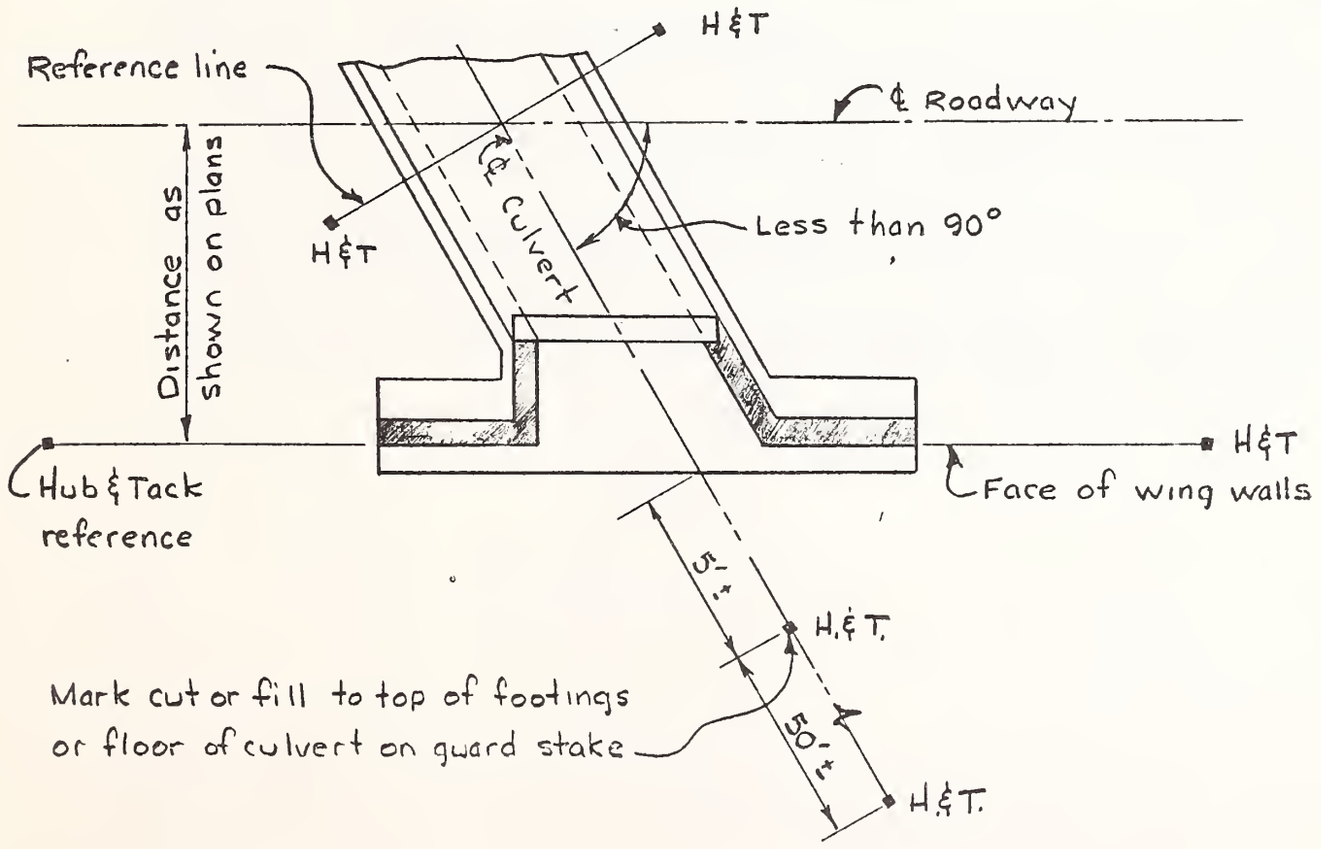


Fig. III-7

Staking of ditch blocks can be done by setting a stake on the shoulder. This stake will then designate the stationing of the ditch black and its height, length and side slopes. The side slopes of the ditch block should start at the inlet or pipe and extend about 10 feet on a slope of 10 to 1 or flatter. The height of the ditch block should be about 1 foot above the top of pipe; be at subgrade elevation; or be about 1' above the inlet elevation.

32.05 Drop Inlets (Fig. III-8)

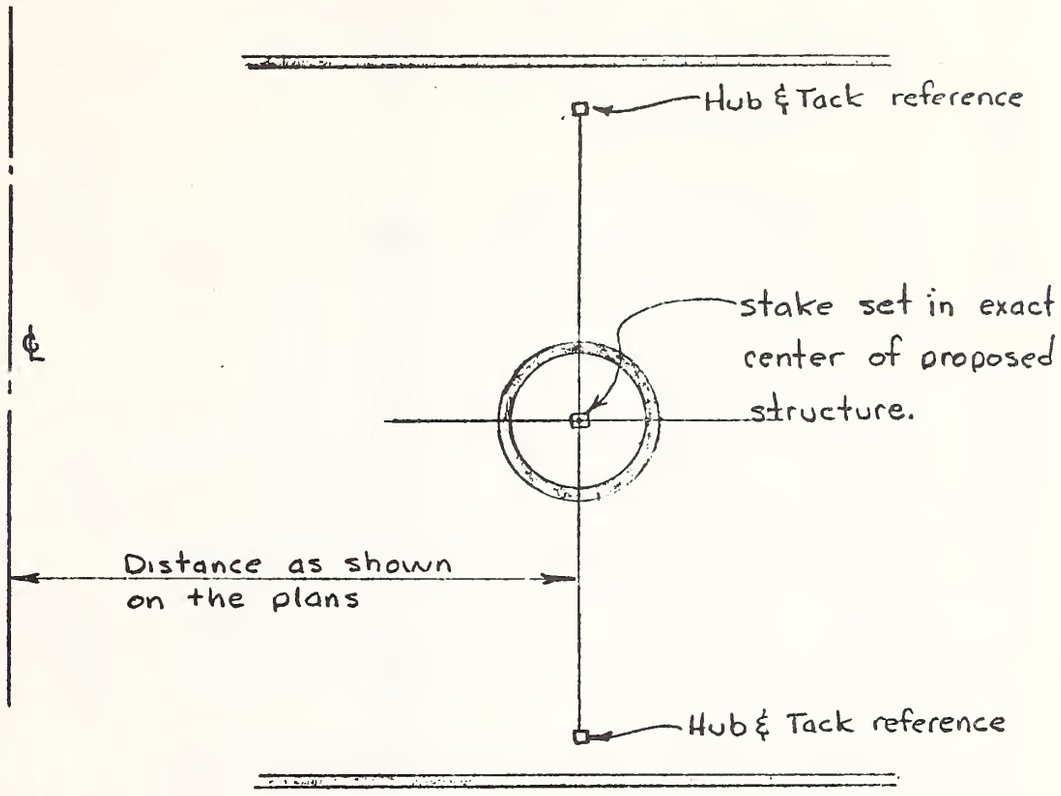
Drop inlets frequently must meet curbs already in place or other in place structures and therefore must be accurately staked to avoid future expensive alterations. There is some flexibility in locating catch basin or curb inlets, but neither of these structures should be placed in the area of a crosswalk.

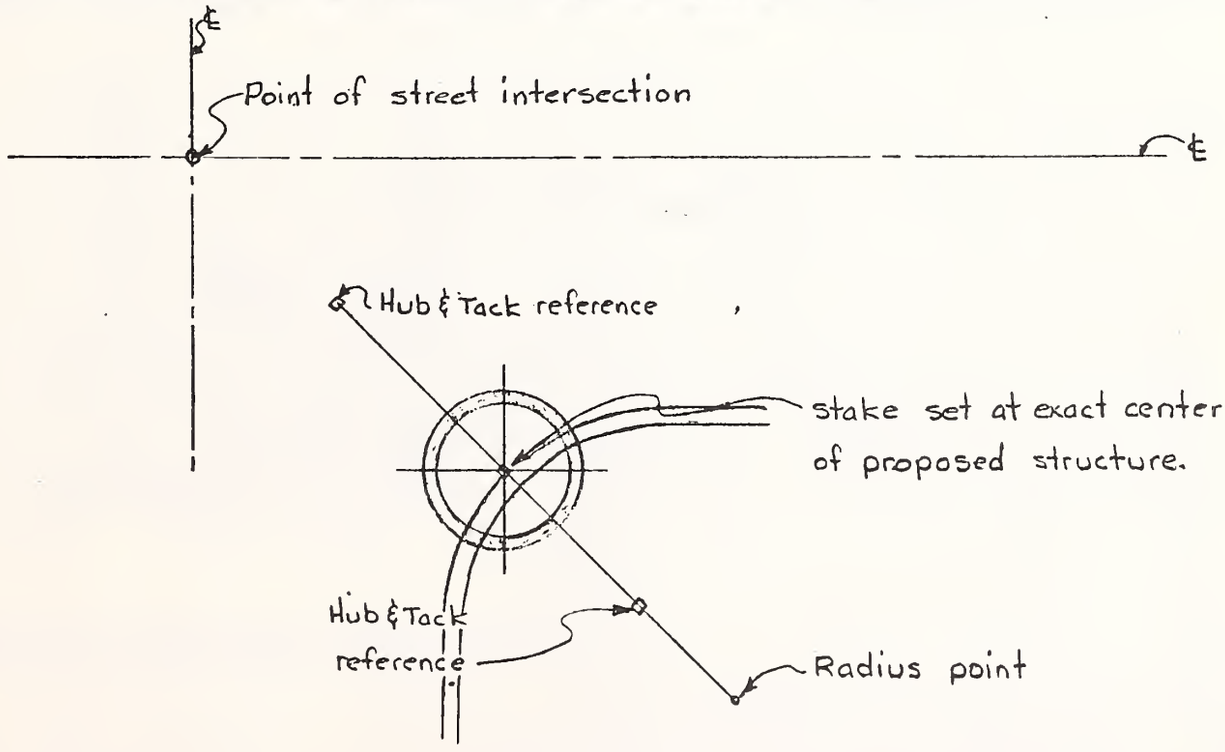
A single stake, hub or marker may be used to identify the center of the inlet structure and two or more hub and tack reference stakes may be used to establish the structure centerline by marking the distance from the center of the structure to the hub and tack locations.

32.06 Curb, Gutter and Sidewalks (Fig. III-9)

A reference line may be run in back of the curb at a constant offset distance and permanently tied with hub and tacks. Reference distances should be marked to the top, back, or to the flow line of the curb whichever method is convenient and compatible with the construction method intended. The vertical difference in the elevation between the reference point and the elevation of the lip of the curb should be included as well as the cut or fill to grade. The reference line stakes may be set at 25 foot intervals, however, the interval of 50 feet may be used on straight alignment. Such existing grade control points as intersecting streets, in-place sidewalks or in-place curbs and gutter must be used to modify the theoretical planned elevations.

STAKING OF MANHOLES, CATCH BASINS & INLETS





Mark reference stakes with the exact distance to the center of the structure. Cut to the flow line & cut or fill to the finished surface of the structure.

Fig. III-8

STAKING METHODS FOR CURB RETURNS

Accessible Radius Point

Set hub & tack at center of radius point, then stake curve.

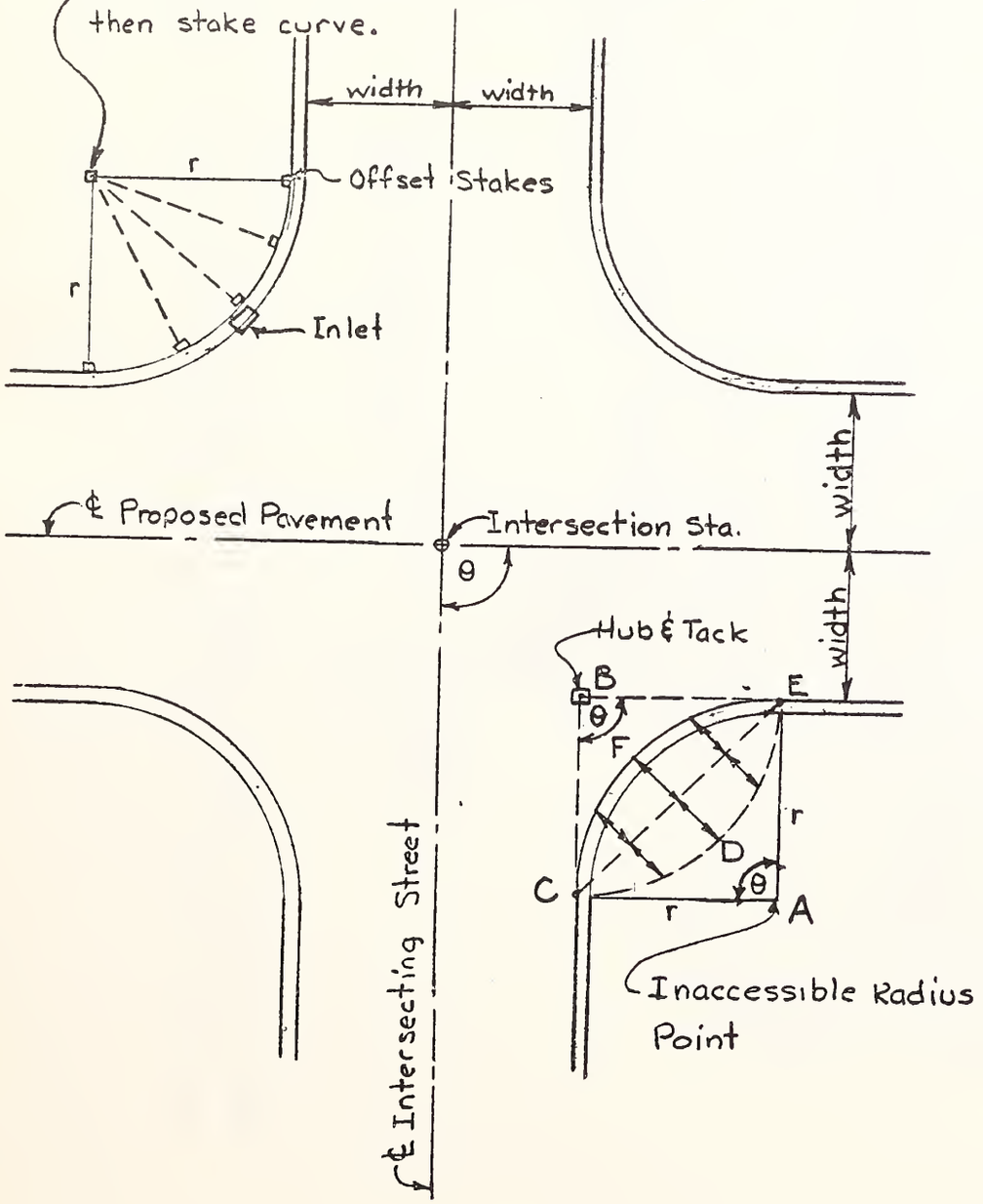


Fig. III-9

Inaccessible Radius Point

To stake curb returns having an inaccessible radius point, set a hub & tack at point B. Use the same radius and θ as if staking from point A, then stake curve CDE. Curve CFE may then be staked by measuring the offset distances from line CE & setting stakes. These offset distances are the same as the corresponding offsets from line CE to curve CDE.

Formulas For Short Radius Curves (10' chords)

I = angle of intersection
D = degree of curvature (10' chord)
T = tangent distance
L = length of curve

$$T = R \tan \tfrac{1}{2} I \qquad L = \frac{10\,I}{D}$$

$$R = \frac{5}{\sin \frac{1}{2} D} \qquad \sin \tfrac{1}{2} D = \frac{5}{R}$$

III-33 CONSTRUCTION SURVEYS FOR MISCELLANEOUS ITEMS

33.00 References

Standard Specifications: Sections 51, 80 through 86, 87 through 90, and 96

33.01 General

The degree of accuracy used in setting construction stakes for miscellaneous items must be consistent with the use of that item and should be adequate to establish the location. Items in this group include, fences, bin walls and retaining walls, traffic control devices, utility items, guardrailing, right-of-way monuments, comfort stations, etc. Some of the items may require a full compliment of stakes precisely set, and other items may only require a mark or a nail placed to indicate correct location.

33.02 Fences

The latest right-of-way map is to be made available for use at the time fences are staked. Last minute changes in right-of-way limits, which may not have been known at the time of original staking, may then be correctly included.

Stakes should be set at the right-of-way line and on right-of-way breaks or curves. Then as a check on accuracy a traverse can be run between these angle points, the angles should be turned to verify the alignment and the traverse closed. Stakes should be set at high points and low points on the right-of-way line so the stakes are intervisible. An adequate number of stakes should be set at a reasonable spacing to allow fence construction without extensive use of surveying instruments. Curved fence alignment may be staked in the usual manner, setting the stakes at regular intervals. Layout of the fence line, to be consistent with the contract pay item, must be made on a line parallel with the top wire of the fence and extend from end post to end post. This new measurement is intended to verify the actual length of fence in place. Do not permit the tape to sag.

33.03 Bin Walls and Retaining Walls

A satisfactory number of cross sections should be taken from a base line offset to the bottom of the bin or retaining wall. The cut or fill from this reference line may then be calculated to other control points of the bin or retaining wall. Establish reference lines and set control points outside of the construction zone to prevent their destruction but permit these points to be readily re-established after excavation.

33.04 Traffic Control Devices

Signs are to be staked at the location indicated on the plans with a lath, stake or hub indicating the location and identifying the sign. The planned position may be moved a few feet one direction or another when obstacles are encountered but care should be taken in positioning signs so they are properly visible and will serve their intended function. Signs may be moved greater distances (10 feet or more) when their visibility will be impaired by trees, buildings, land forms or other permanent obstacles after approval is received from the Division Construction Supervisor, FHWA Engineer, or Construction Bureau. The severity of the move will dictate the need for consulting higher authority.

The Traffic Design Unit will furnish technical assistance, if needed, on projects containing such bid items as permanent signing, traffic signalization or lighting. The Project Manager may request such assistance from the Division Construction Supervisor, through his superiors. In contrast with signs set in rural locations that may be moved to better fit field conditions, a lighting or signal project is intended to function at a specific location and has its structure design for that location only. Therefore, changes in the design or location; even though these changes may be needed and will obviously fit, must receive the attention of the Traffic Design Unit via the Construction Bureau.

33.05 Utilities

Most utility moves, relocations or readjustments are made by the utility owner prior to construction, which will generally confine the staking required by state forces to that necessary for establishing horizontal and vertical clearance controls. Utilities that are being installed, relocated or readjusted as a part of the contracted work will require staking necessary to provide alignment and grade in addition to horizontal and vertical clearance controls. A careful review should be made of the proposed roadway construction so that adequate clearance is provided across road approaches, and the main line, so that the intended position of the utility does not conflict with use of other facilities.

A full survey party should not be used if one or two persons can do the job adequately. With proper handling and advance coordination, most of the utility relocation features can be set to allow a minimum amount of resurveying.

33.06 Guard Rail

Special installation instructions are shown on the plans and on the standard drawing sheets for locating guardrail and guide post installations but it is difficult for a designer to accurately

To All Holders of The Survey Manual

From C. R. Mackey, Chief - Construction Bureau

This Section covers the new Right-of-Way Monumentation Procedure and the enclosed sheets replace 33 - 3 and 33 - 4 in the Survey Manual.

Drawing No. 104 in the present Standard Drawing book will be deleted and the attached drawing figure 3 - 10 will only be shown in the Survey Manual.

CRM/ka

pinpoint these facilities. Therefore, it is necessary to perform a field check of these locations just prior to staking. Adjustments may be necessary in the lengths and locations. The Project Manager should obtain the proper authorization before proceeding with staking when large differences in quantities are encountered.

Several different staking techniques have been successfully employed in the past. The choice of which to use will be determined by the Project Manager. Hubs and tacks or nails set for proper alignment and grade may be placed directly on line or may be offset. Parabolic flares may be established from the offset line. Guardrail on tangents may be staked by marking each end of the run of guardrail or the location of each post on a tangent run may be staked individually. No matter what staking method is used, the Project Manager should insist on a product, that when finished, presents a satisfying appearance in alignment and grade.

33.07 Right-of-Way Monuments

Right-of-way monuments are to be staked at the locations shown on the plans and those locations referenced by the use of hubs and tacks and an iron pin. The center of the right-of-way monument is to be set on the right-of-way line. The location of the hubs and tacks, iron pins and changes in right-of-way widths are to be detailed and demensioned in the transit notes. A separate notebook will then be set up during construction to show the final location of all right-of-way monuments and their referenced ties to centerline or witness markers.

1. Right-of-Way monuments will be set at all points where the width of the right-of-way changes, and at angle points, the P.C. and P.T. of simple curves, and the T, S, and S, T, or spiral curves, also the beginning and end of all projects, R/W monuments will not be used on stationing and distance from centerline will be stamped on all monuments.

2. Centerline Monuments will be set at all angle points, the P.C. and P.T. of simple curves and the T.S. and S. T. of spiral curves. Also, they shall be placed at all equations and high points so at least one other monument on centerline may be viewed. On urban project monuments shall be placed on centerline at all intersecting streets. Stationing will be stamped on all monuments.

3. R/W reference markers are to be set at all R/W monuments. R/W reference markers should be placed twelve (12) inches inside of the R/W monument.

4. Reference points are to be set at all R/W monuments. Reference points should be placed three (3) feet inside the R/W monument. The reference point will be a 5/8" X 30" iron pin.

5. Project no. plate - Plate shall be bolted to a 42" steel V-Post at the beginning and end of each project.

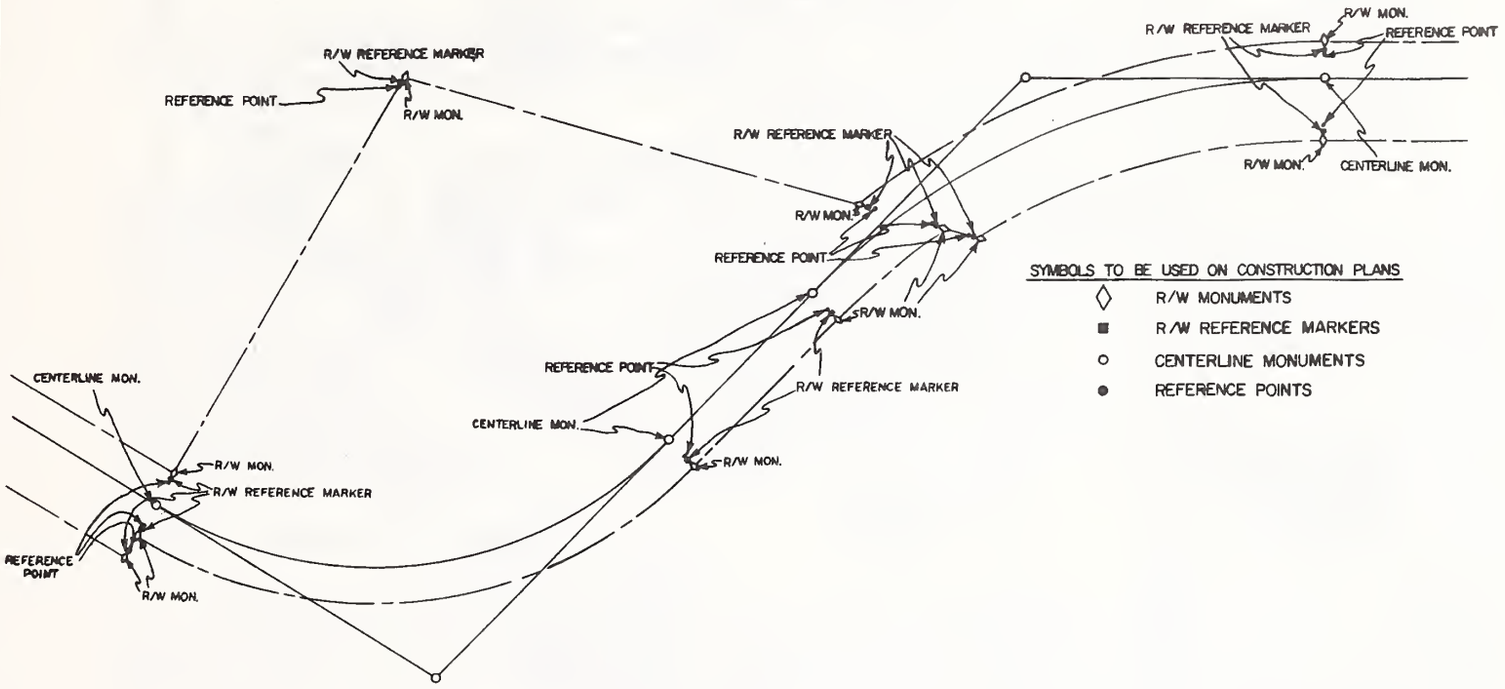
See Fig. III-10

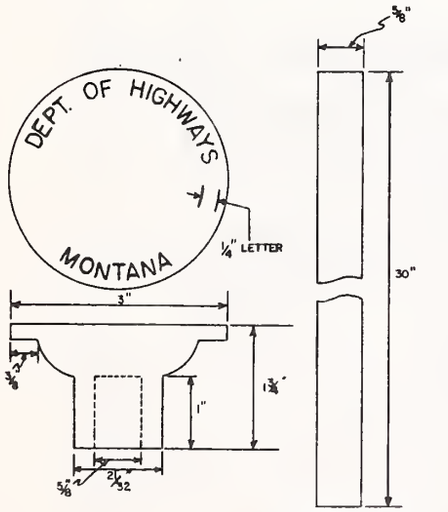
33.08 Comfort Stations

Staking of comfort stations involves an entirely different concept other than the regular route surveying done by highway engineers. Prefabricated materils are used extensively in the walls and partitions of the building. Drain fields are needed, underground sprinkling systems may be required and such surface facilities as driveways, sidewalks and locations for planting trees and shrubs are sometimes a necessity.

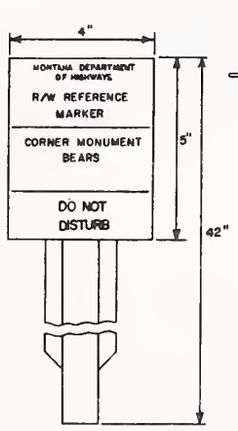
A careful review of the plans for the building site and attendant facilities should be made before staking is begun. Base lines or reference lines should be established at the proper locations and their control points referenced to prevent destruction. Line and grade must be set for the footing of the building and sewer facilities and a convenient reference provided for carpenters or other workmen to establish batter boards and other construction aids to fit the line and grade.

RIGHT-OF-WAY MONUMENTATION

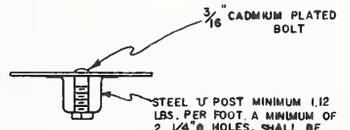




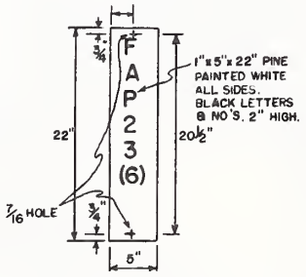
REFERENCE PIN AND RIGHT-OF-WAY STAKE (BAR-5/8" REBAR)



RIGHT-OF-WAY REFERENCE MARKER


3/16" CADMIUM PLATED BOLT
STEEL 'U' POST MINIMUM 1.12 LBS. PER FOOT. A MINIMUM OF 2, 1/4"ø HOLES, SHALL BE DRILLED OR PUNCHED ON 1" CENTER FROM THE TOP OF THE POST PRIOR TO PAINTING.

PROJECT NO. PLATE SHALL BE MOUNTED ON THE SAME TYPE POST USED FOR R/W REFERENCE MARKER. EXCEPT 2, 1/2" ø HOLES SHALL BE DRILLED OR PUNCHED ON 1" CENTER FROM TOP OF POST @ 21/4 FROM TOP OF POST.



PROJECT NO. PLATE

R/W REFERENCE MARKERS ARE TO BE SET AT ALL R/W MONUMENTS. R/W REFERENCE MARKERS SHOULD BE PLACED TWELVE (12) INCHES INSIDE OF THE R/W MONUMENT.

REFERENCE POINTS ARE TO BE SET AT ALL R/W MONUMENTS. REFERENCE POINTS SHOULD BE PLACED THREE (3) FEET INSIDE THE R/W MONUMENT. THE REFERENCE POINT WILL BE A 5/8" X 30" IRON PIN.

CENTERLINE MONUMENTS - WILL BE SET AT ALL ANGLE POINTS, THE P.C. AND P. T. OF SIMPLE CURVES AND THE T. S. AND S. T. OF SPIRAL CURVES. ALSO, THEY SHALL BE PLACED AT ALL EQUATIONS AND HIGH POINTS SO AT LEAST ONE OTHER MONUMENT ON CENTERLINE MAY BE VIEWED. ON URBAN PROJECTS MONUMENTS SHALL BE PLACED ON CENTERLINE AT ALL INTERSECTING STREETS.

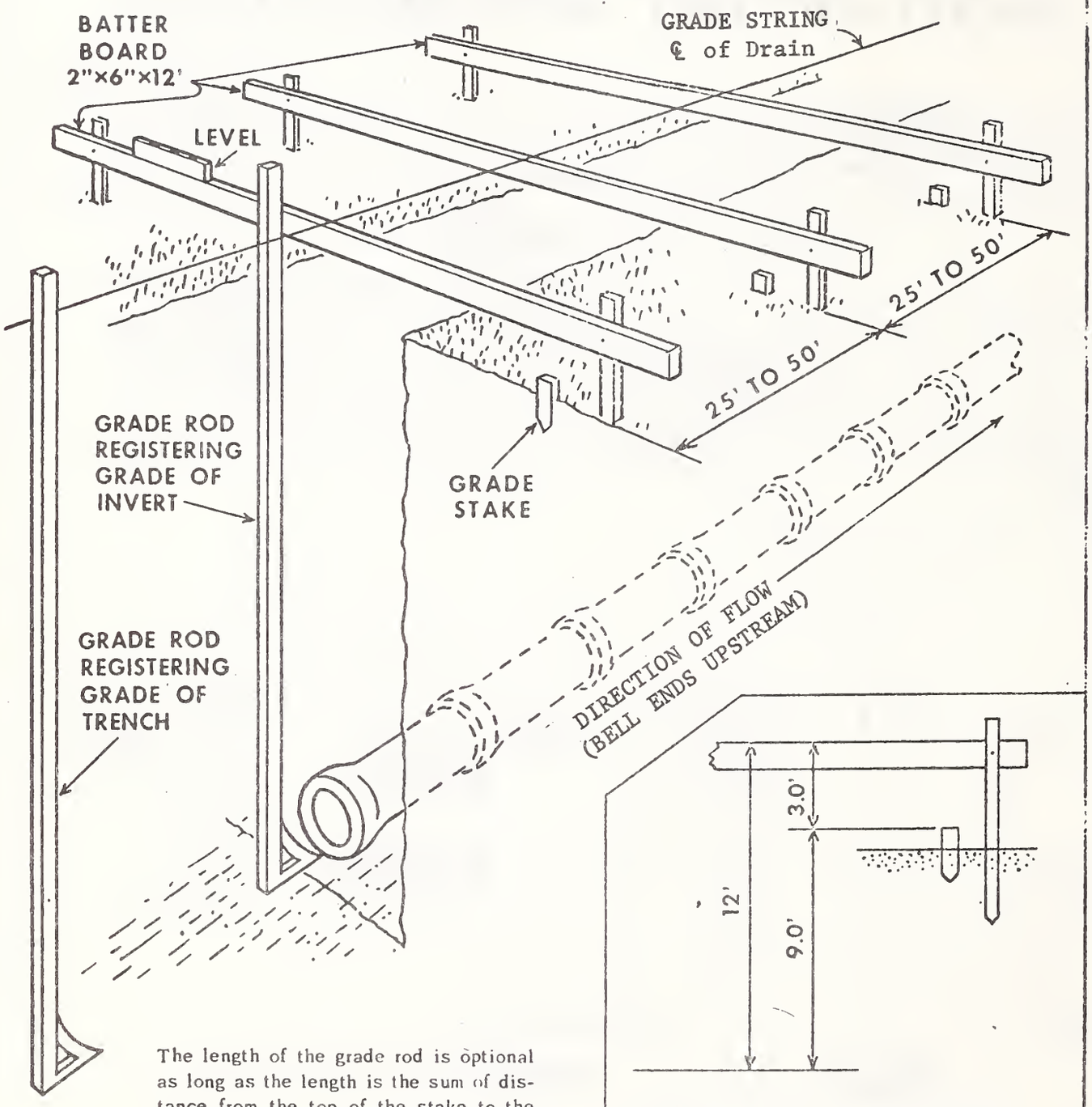
STATIONING WILL BE STAMPED ON ALL MONUMENTS.

RIGHT-OF-WAY MONUMENTS WILL BE SET AT ALL POINTS WHERE THE WIDTH OF THE RIGHT-OF-WAY CHANGES, AND AT ANGLE POINTS, THE P. C. AND P. T. OF SIMPLE CURVES, AND THE T, S, AND S, T, OF SPIRAL CURVES, ALSO THE BEGINNING AND END OF ALL PROJECTS, R/W MONUMENTS WILL NOT BE USED ON STATIONING AND DISTANCE FROM CENTERLINE WILL BE STAMPED ON ALL MONUMENTS.

PROJECT NO. PLATE - PLATE SHALL BE BOLTED TO R/W REFERENCE POST DIRECTLY BELOW THE MARKER SIGN AT THE BEGINNING AND END OF EACH PROJECT.

Fig. III-10

METHOD OF STAKING TILE UNDERDRAIN AND SEWER



The length of the grade rod is optional as long as the length is the sum of distance from the top of the stake to the flow line of the tile and from the top of the stake to the top of the batter board.

The illustration shows an 8 ft. grade rod, the cut on the grade stake is 5.0' to flow line of tile. 8' - 5' = 3'. Therefore the batter boards will be set 3 ft. above grade stake.

EXAMPLE GRADE BOARD SET-UP:

CUT TO SEWER INVERT FROM STAKE = 9.0'

A 12 FOOT GRADE BOARD IS CHOSEN

12.0 - 9.0 = 3.0

THE BOARD IS THEN PLACED 3.0' ABOVE THE STAKE

Fig. III-11

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pinpoint these facilities. Therefore, it is necessary to perform a field check of these locations just prior to staking. Adjustments may be necessary in the lengths and locations. The Project Manager should obtain the proper authorization before proceeding with staking when large differences in quantities are encountered.

Several different staking techniques have been successfully employed in the past. The choice of which to use will be determined by the Project Manager. Hubs and tacks or nails set for proper alignment and grade may be placed directly on line or may be offset. Parabolic flares may be established from the offset line. Guardrail on tangents may be staked by marking each end of the run of guardrail or the location of each post on a tangent run may be staked individually. No matter what staking method is used, the Project Manager should insist on a product, that when finished, presents a satisfying appearance in alignment and grade.

33.07 Right-of-Way Monuments

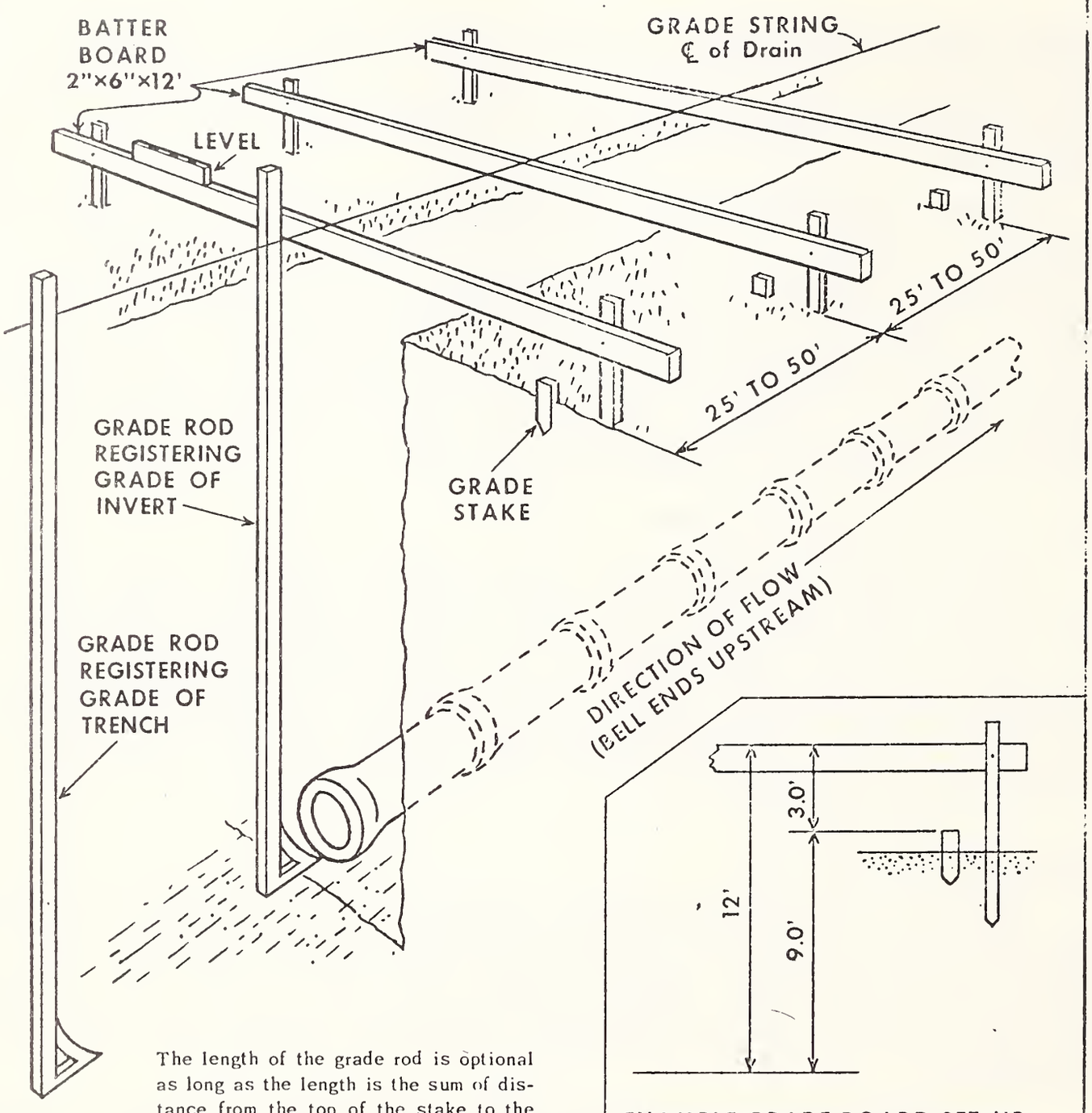
Right-of-way monuments are to be staked at the locations shown on the plans and those locations referenced by the use of hubs and tacks and an iron pin. The back face of the right-of-way monument is to be set on the right-of-way line. The location of the hubs and tacks, iron pins and changes in right-of-way widths are to be detailed and dimensioned in the transit notes. A separate notebook will then be set up during construction to show the final location of all right-of-way monuments and their referenced ties to centerline or witness markers.

33.08 Comfort Stations

Staking of comfort stations involves an entirely different concept other than the regular route surveying done by highway engineers. Prefabricated materials are used extensively in the walls and partitions of the building. Drain fields are needed, underground sprinkling systems may be required and such surface facilities as driveways, sidewalks and locations for planting trees and shrubs are sometimes a necessity.

A careful review of the plans for the building site and attendant facilities should be made before staking is begun. Base lines or reference lines should be established at the proper locations and their control points referenced to prevent destruction. Line and grade must be set for the footing of the building and sewer facilities and a convenient reference provided for carpenters or other workmen to establish batter boards and other construction aids to fit the line and grade.

METHOD OF STAKING TILE UNDERDRAIN AND SEWER



The length of the grade rod is optional as long as the length is the sum of distance from the top of the stake to the flow line of the tile and from the top of the stake to the top of the batter board.

The illustration shows an 8 ft. grade rod, the cut on the grade stake is 5.0' to flow line of tile. 8' – 5' = 3'. Therefore the batter boards will be set 3 ft. above grade stake.

EXAMPLE GRADE BOARD SET-UP:

CUT TO SEWER INVERT FROM STAKE = 9.0'

A 12 FOOT GRADE BOARD IS CHOSEN

12.0 – 9.0 = 3.0

THE BOARD IS THEN PLACED 3.0' ABOVE THE STAKE

Fig. III-10

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BRIDGE CONSTRUCTION SURVEYS

35.00 References

Standard Specifications: Articles 05.02, 05.03, 05.08

35.01 Responsibilities for Survey Work

This Article separates the contractor's responsibilities and work from those of the State regarding layout and survey work as defined in Article 05.08 of the Standard Specifications.

The intention is to define the method which will provide an independent check of all structure layout. This will be to the mutual benefit of the contractor and the Department of Highways in that delays and expenses incurred due to the improper location of structure units will be held to a minimum. This will also aid in maintaining engineering costs at acceptable levels. It is not the intention to use these instructions as a reason for State personnel to sit idle while the contractor is doing survey work justly the responsibility of the State.

A. Department of Highways Work

Project personnel shall provide the contractor with centerlines and bench marks in accordance with Article 05.08 of the Standard Specifications. The centerline will be marked by clearly identified points set in the immediate vicinity of each structure unit under construction. These points will be in addition to the primary survey controls ordinarily established for references. It is intended that these points be set such that the contractor will be able to proceed with the remaining layout by means not requiring the services of someone especially skilled in surveying i.e., sufficient controls will be set so the contractor can use:

1. Batter Boards
2. String Lines or
3. Simple instrument set up to shoot straight lines from one point to another.

The State shall furnish bench marks which shall include:

1. Cut stakes for footing excavation
2. Beam seat elevations for brush hammer leveling and/or shims
3. Span tenth point elevation for setting deck slab forms.
4. Grade on structural steel splices.

The Department of Highways is responsible for the accuracy of the bench marks and points described above according to Article 05.08 of the Standard Specifications.

B. Contractor's Work Responsibilities

The contractor will be required to complete the remaining layout and to set and maintain the location of excavation, piling, cofferdams, forms, etc. in accordance with these points. This work shall be the responsibility of the contractor.

C. Checking and Inspection Work

It is MANDATORY that the Project personnel physically check the contractor's layout for line and grade on the following items in particular at the stage of work indicated.

1. Cofferdams - When ring is set and prior to driving sheets.

2. Footing excavation - Prior to beginning excavation.

3. Piling - Prior to driving piles.

4. Forms - Prior to authorizing the contractor to order and place concrete.

5. Embedded Items - Prior to authorizing the contractor to order and place concrete.

In some cases it is the best interest of the Department of Highways to perform intermediate checks prior to the above mentioned stages of work i.e. - checking of form locations prior to placing large quantities of reinforcing steel where moving the form would result in a major operation of dismantling, shifting the reinforcement and additional structure excavation. Discretion should be exercised in making such checks so they do not become a substitute for the mandatory checks described above or become a substitute for the layout that is the contractor's responsibility.

It is recognized that occasions will arise when demands on Project Personnel will exceed their capacity to perform all required inspection at the particular time desired by the contractor. In these cases, it shall be the RESPONSIBILITY of the Project Manager or the person in charge to require the contractor to set priorities for the work. IN NO CASE will work be allowed to continue without the required inspection.

The need for additional inspection personnel and/or more efficient procedures and scheduling is indicated if it becomes necessary to continually set such priorities.

PLEASE CALL SPECIFIC ATTENTION TO BRIDGE CONSTRUCTION STAKING AT ALL PRECONSTRUCTION CONFERENCES.

35.02 Preliminary

A. Check dimensions on bridge plans prior to staking. Particularly check elevations from finished grade down through deck slab, girder, shoes, crossbeams, columns and footings. Check span lengths, skew angles, etc. for horizontal control.

B. Review road or other plans for construction features that could affect the layout and location of references for the structure; and discuss any special embankment requirements with roadway Project Manager.

C. Check alignment and stationing of roadway centerline as staked in field. Be certain that lines and stations already staked on the ground are as shown on the plans.

D. Determine if bench marks as shown on plans and proposed for establishment of vertical control are in place and usable.

E. Plan layout and referencing to provide control of work with required accuracy in the most economical manner. Place references where they will serve the intended purpose for as long as required; where they are readily usable; and where they are secure from construction operations. (If such is possible). That is, do not place references in center of projected ramp road, or in a place where a portion of substructure will not be visible.

F. BEFORE construction work may begin on any structure, layout, referencing and field checking of primary horizontal and vertical control must be complete.

35.03 Horizontal Control - General

Due to terrain conditions and other considerations at each site, it is not practical to rigidly adhere to any one standard method of layout and referencing. Figure No. 1 through No. 5 are intended for examples of minimum acceptable methods. When it is necessary to vary from these methods, the following basic principles of good engineering practice shall be adhered to:

1. Methods of distance and angular measurement will be used to produce work that is within the following permissible limit of error:

   a. Cast in place structures - 1/4"/100' or 1 in 5000

   b. Prestressed beam structures - 1/8"/Span or 1 in $\frac{\text{Span Length}}{0.01}$

   c. Steel Structures-1/8"/Span or 1 in $\frac{\text{Span Length}}{0.01}$ (Centerline Brg to Centerline Brg)

   Example: 50' Span Accuracy required = 1 in 5000

   100' Span Accuracy required = 1 in 10,000

   200' Span Accuracy required = 1 in 20,000

2. LAYOUT SHALL BE CHECKED BY A METHOD INDEPENDENT OF THE METHOD USED INITIALLY. This will be entered in a set of notes clearly showing the method of checking used, all computation, observed errors and the accuracy of original work as compared to check.

3. Reference points should be established by methods which will permit the re-establishment of the layout to the original accuracy.

4. References will be established in sufficient numbers, in the proper locations, to permit accurate and timely control of the work.

5. Reference points will be clearly identified and flagged on the ground. Notes shall be prepared such that a person not familiar with the project will be able to readily locate and use the reference system and re-establish points destroyed or disturbed. RECORD LAYOUT AND REFERENCES IN FIELD NOTES.

6. At least one line of reference, located beyond the outermost portion of substructure units, should be established to permit a check of span lengths along the reference line to detect divergence from plan lines.

35.04 Horizontal Control - Tangent Dryland Structure

A. Preliminary - Check instrument for accuracy. Adjust if necessary. Standardize chain, if possible, for various conditions of use.

B. Procedure - See Figures 1, 2 and 3.

1. Establish centerline of structure, centerline of roadway or other control line as required. Reference this line with two (2) points on either end of bridge. Witness points outside construction limits,

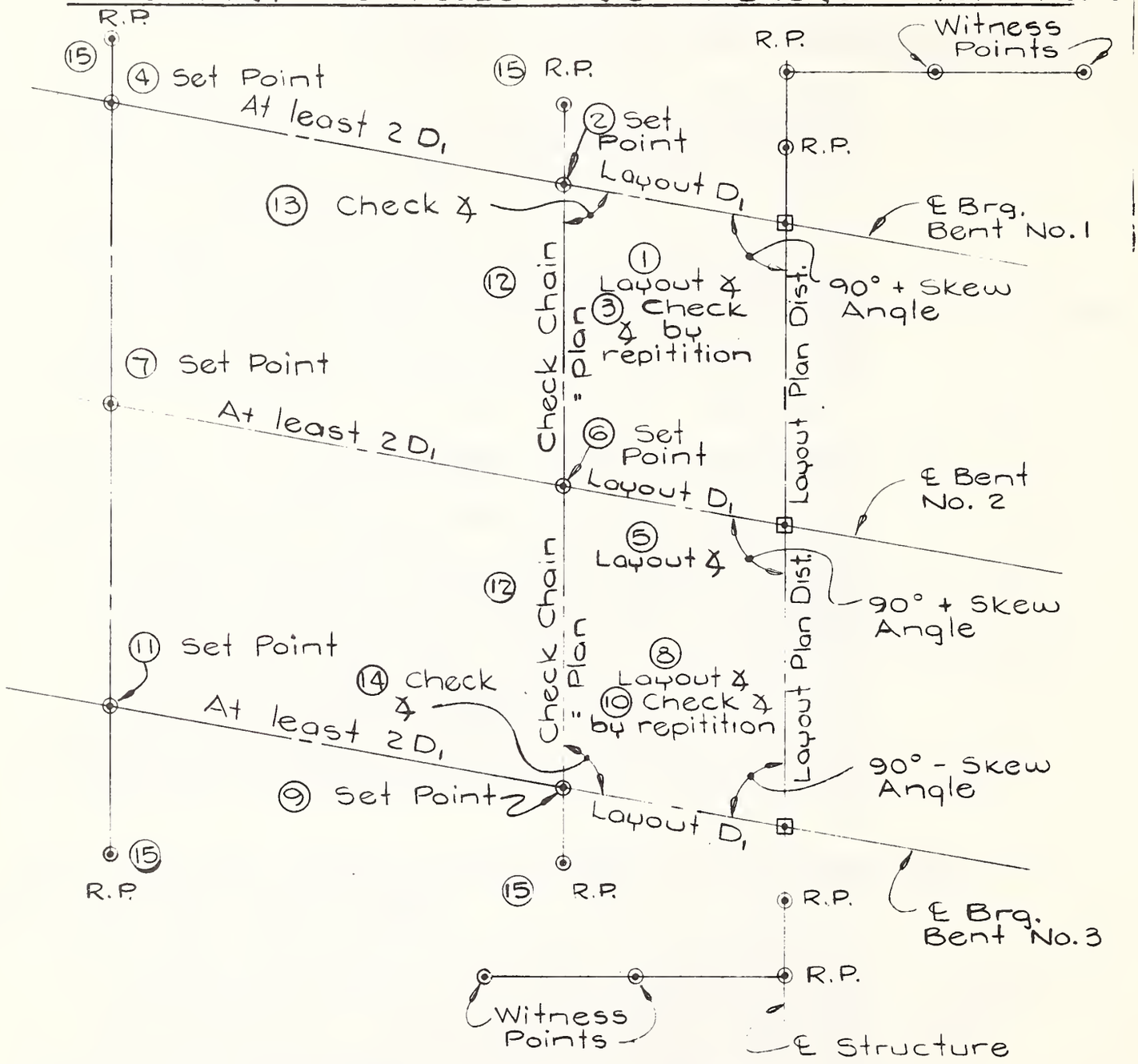
2. Establish points at the intersection of centerline of structure, etc. with centerline of bearing or centerline of Bent of all the various units of the substructure. Place guard stakes on these points clearly identifying them. Example: Bent No. 2 Westbound - Centerline of Bent at Centerline of Roadway - Station 484+75.00.

3. Reference the points established in (2). See Figures No. 1 and No. 2 for reference layouts. Use method of turning angles and chaining distances consistent with accuracy required. Separate references a distance sufficient to minimize effects of normal sighting and instrument set-up errors. Clearly identifying the reference points on the ground. Include the following: (a) Line referenced. (b) Bent No. (c) Distance from centerline of structure. Record reference points in notes. Include information such as distance from centerline of structure, topography useful to approximately locate points, (ties), relationship to structure and type of point set.

4. Perform independent check of layout. Enter in notes a sketch of method used, computations, observed errors, and errors expressed as a ratio. See Figures No. 1 and 2 for examples. On skewed structures, provision should always be made to allow check chaining of span lengths at a reference line outside of the outermost portion of the bents. (See Figure No. 3). This is a necessary check to assure that the bent centerlines are not incorrectly diverging or converging.

5. Steps 1, 2, 3 and 4 constitute the primary control and must be performed before construction begins on any portion of the structure. If construction is allowed to proceed on a portion of a structure before these steps are accomplished, it becomes extremely difficult to complete the layout in accordance with good practice.

PRIMARY CONTROLS - GRID REFERENCE SYSTEM 35-6

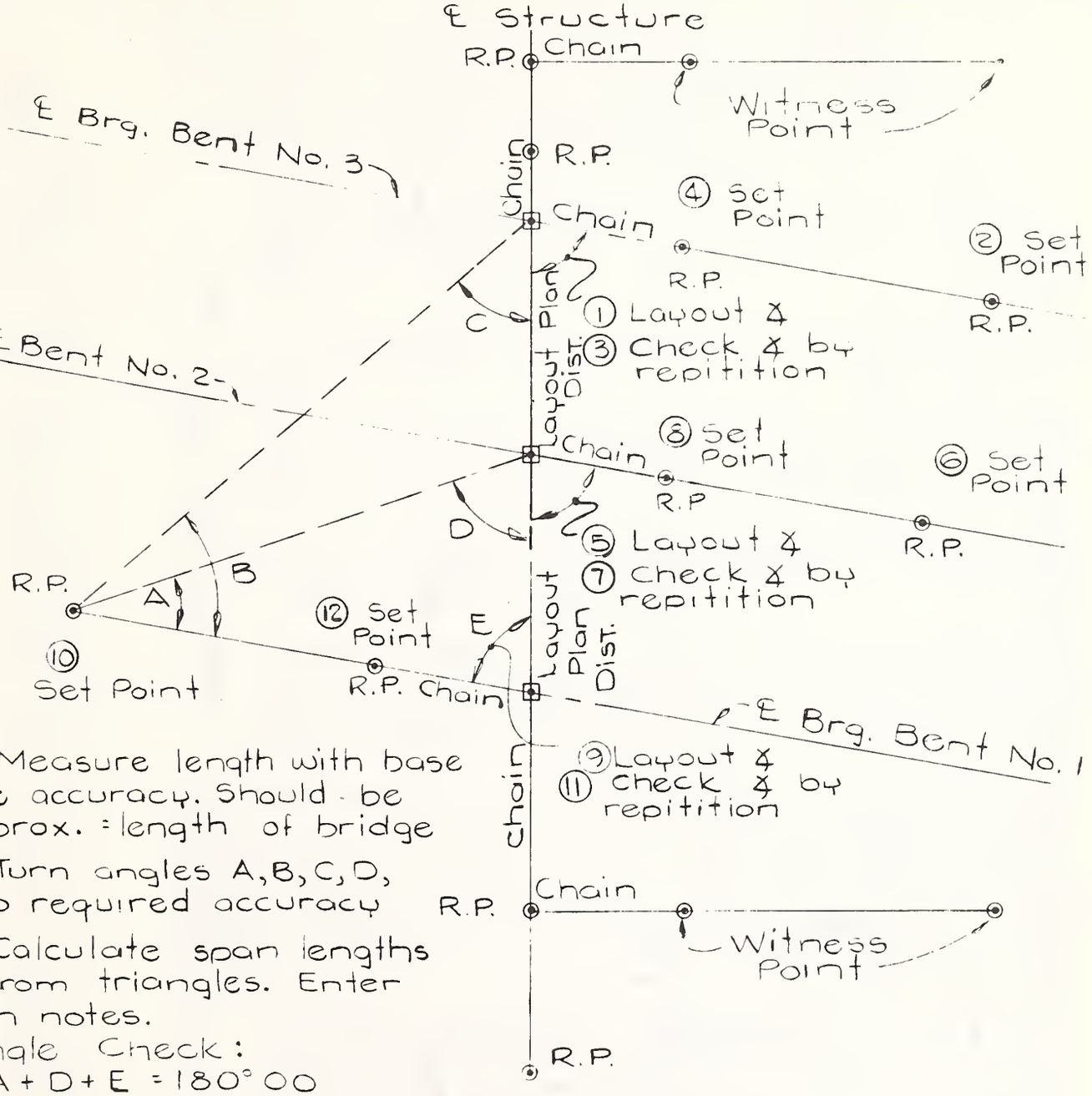


② Indicates sequence
⊙ Reference point
Angle checks:
∡③ + ∡⑬ = 180° 00′
∡⑩ + ∡⑭ = 180° 00′
∡③ + ∡④ + ∡⑩ + ∡⑭ = 360° 00′

Note: This method provides independent checks of chaining, angles and convergence or divergence of bearing lines. Show reference system in notes with lineal and angular errors found in checks.

FIGURE No. 1

PRIMARY CONTROLS - RANDOM REFERENCES & TRIANGULATION



⑬ Measure length with base line accuracy. Should be approx. = length of bridge

⑭ Turn angles A, B, C, D, to required accuracy

⑮ Calculate span lengths from triangles. Enter in notes.

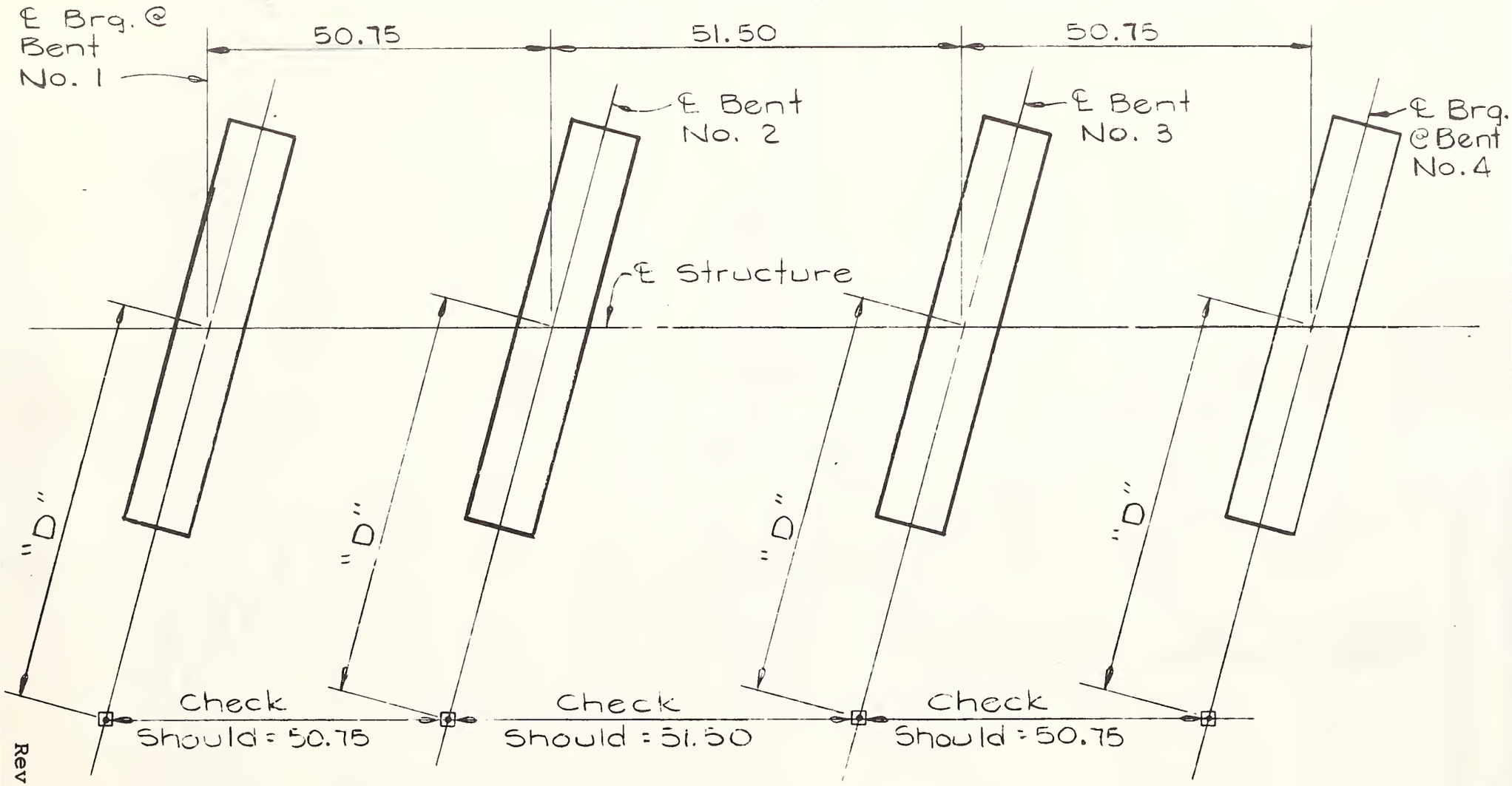
Angle Check:
A + D + E = 180° 00
B + C + E = 180° 00

⑯ Calculate lineal & angular error & enter in notes with sketch of primary controls references.

Note: The above system illustrates the minimum acceptable primary controls. If possible set one R.P. per bent at same distance from ℄ structure on same side and check chain between to ensure bent lines are parallel.

FIGURE No. 2

CHECK OF SKEW ANGLES & REFERENCE LINE



Note: This relatively easy check will determine if the skew angles laid out are parallel to each other and not converging or diverging. The hubs and tacks placed for this may be utilized for construction controls.

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35-8

FIGURE NO. 3

6. Should the situation arise out of absolute necessity, the following procedure shall be used to allow construction before all primary controls have been established.

   (a) Establish the location of one sub-unit (bent, pier, abutment, etc.). This sub-unit becomes the anchor point for the layout of the rest of the structure.

   (b) Proceed with layout of rest of structure by direct measurement from anchor point sub-unit.

   (c) The use of this method requires that establishment of construction controls proceed in order from the substructure unit first located.

   (d) This method requires that direct measurement be made to check each new substructure unit against those already constructed.

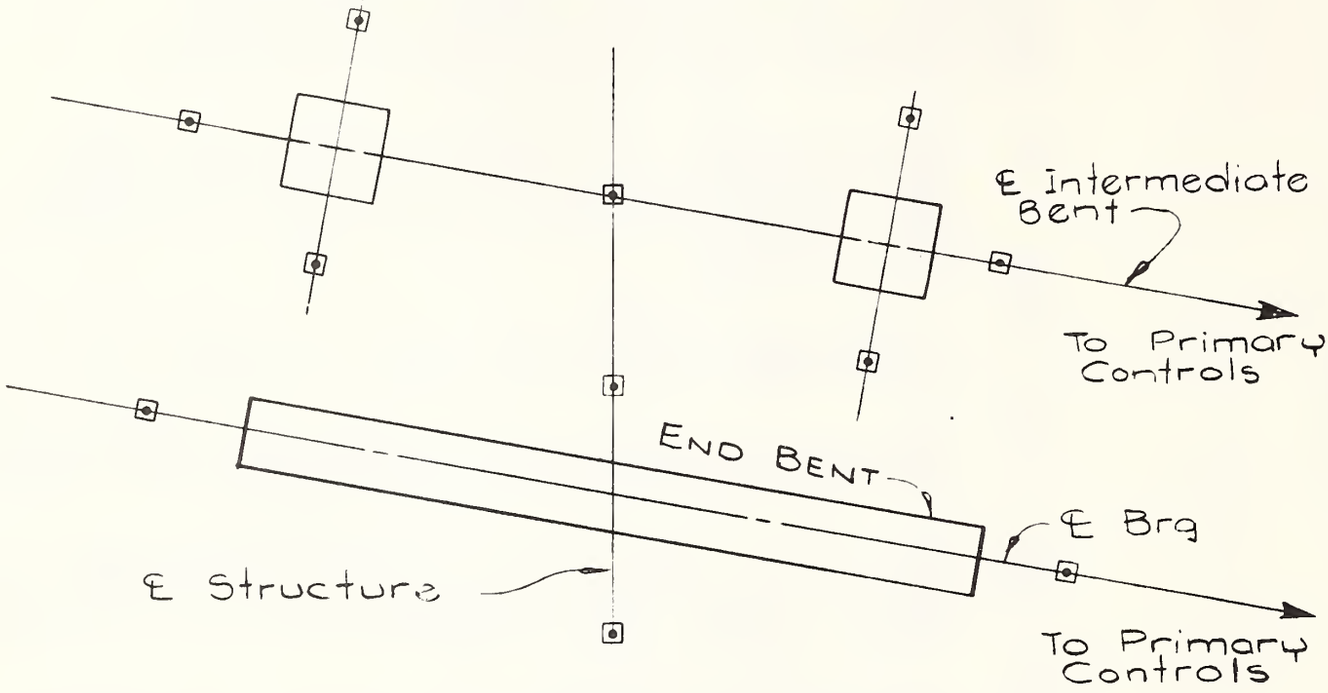
   (e) This procedure shall also be used in instances where primary controls can not be re-established due to having been destroyed or disturbed during the course of construction.

7. If check shows that layout and references are within limits of permissible error, proceed with layout of construction control points. In the interest of consistency and uniformity and in keeping with policy, the following procedure for establishing construction control points is recommended. (See Figure No. 4).

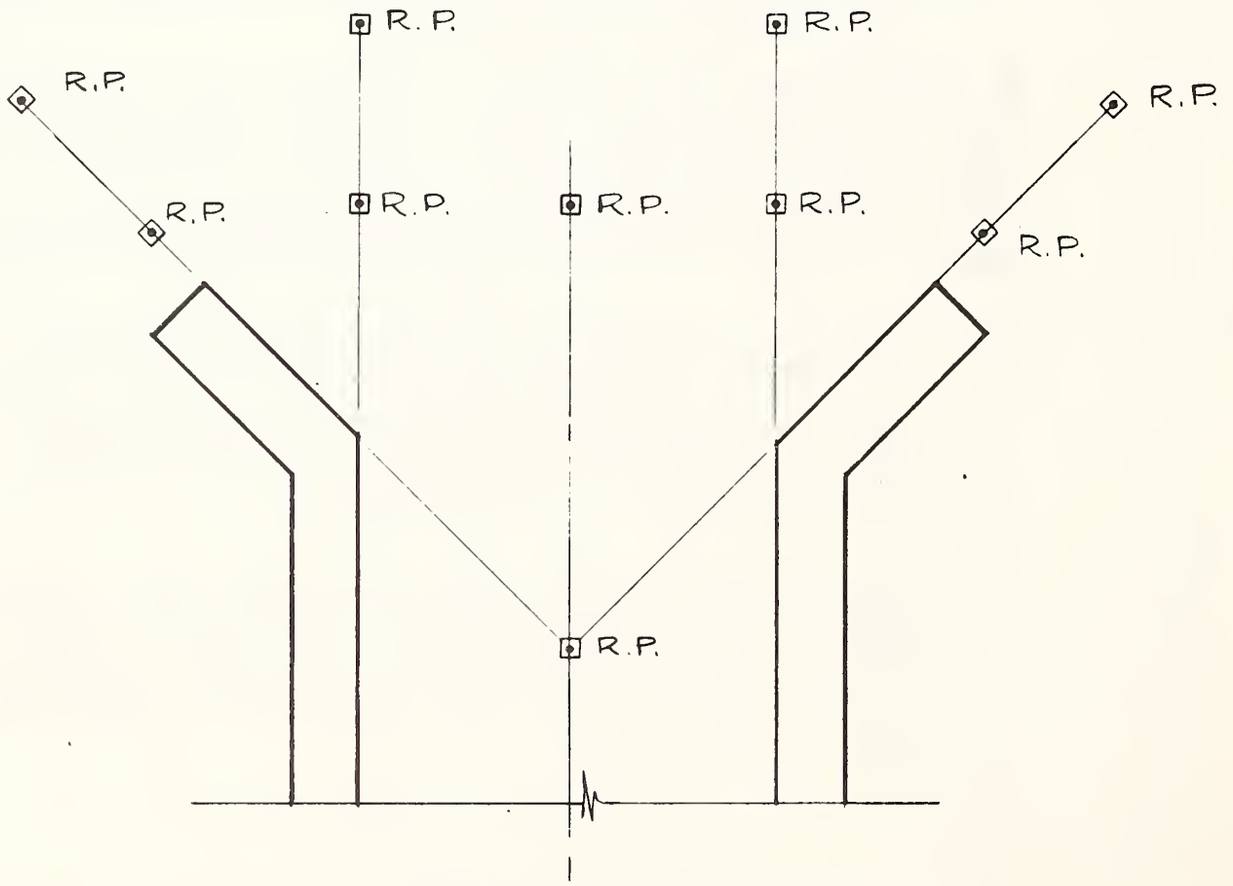
   (a) Layout and establish points on centerline of footings, abutments, sufficient to permit the contractor to locate footing excavation limits, layout piling, set footing and column forms, etc. by means of batterboards and string lines or other means as he may choose.

   (b) It is required that the contractor lay out footing excavation limits, piling, set forms on line, etc. from the points furnished. His layout shall then be checked by the State crew prior to placement of the items. This will result in an independent check of the work.

CONSTRUCTION CONTROLS
TYPICAL GIRDER STRUCTURE



JUNIOR GRADE SEP., RET. WALL, BOX CULVERT



TYPICAL BOTH ENDS

FIGURE NO. 4

(c) After the first substructure unit has been constructed, the location of subsequent units should be checked in reference to previously constructed units by careful direct measurements to insure proper fit of superstructure work. This is particularly true for crossbeams. Measurements should take into account the effects of slope, temperature and tension.

35.05 Horizontal Control - Dryland Structure on Curve

1. Establish bridge chord or other control line as required. Reference with two (2) points on either end of bridge. Witness points outside of construction limits as necessary to permit re-establishment of line.

2. Establish points at intersection of bridge chord or control line and centerline of bearing or centerline of Bent. Identify these points with guard stakes and in notes with same information as structure on tangent. See Section 35.04 B 2.

3. Reference the points established in 2. See Figure No. 1 and procedure outlined in Section 35.04 B 3. In making layout it will be necessary to perform computations for various distances to utilize the system shown; however, use of this system will result in an independent check of angles and of span distances on centerline and at the reference lines.

4. ALWAYS PERFORM INDEPENDENT CHECK OF LAYOUT. Follow procedure as stated in Section 35.04 B 4, B 5, B 7 for tangent structure.

5. Pay particular attention to offset distances from chord line to centerline of Bent or centerline of footing. Check plan distances in office on paper prior to layout and check completed field layout. Layout errors in this are very common.

35.06 River Crossing - Triangulation (See Figure 5, 6, 7, 8, 9, 10)

The following procedure will be used in staking all river crossings, and all other structures where the width of the stream, rough terrain, or other conditions prevent direct measurement on centerline by ordinary chaining methods to the necessary degree of accuracy.

1. Preliminary - Check instrument for proper adjustment. It is absolutely necessary to standardize the chain used for base line measurement.

TRIANGULATION FOR INACCESSIBLE STRUCTURES

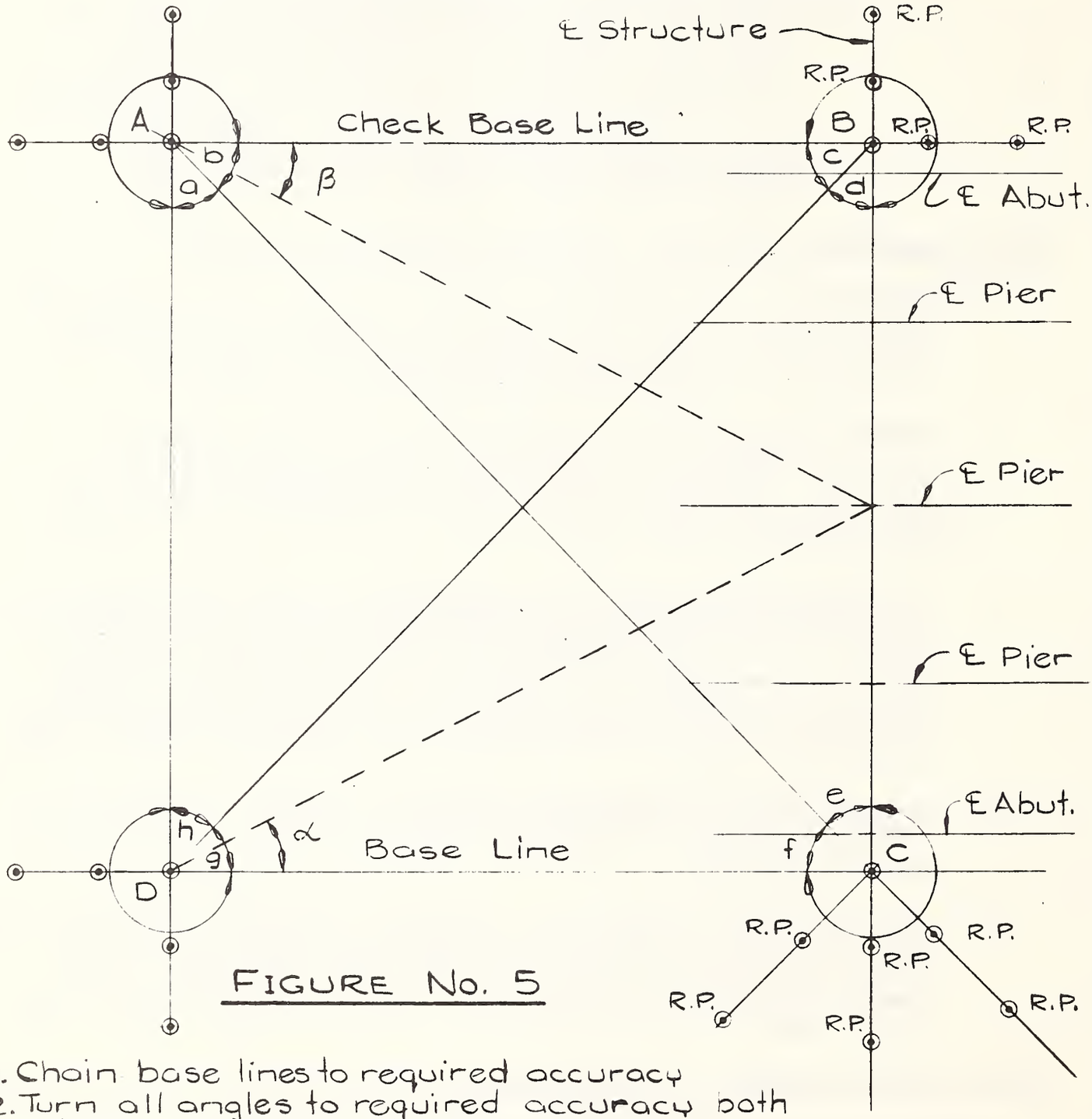


FIGURE No. 5

1. Chain base lines to required accuracy
2. Turn all angles to required accuracy both interior & exterior (Close horizon)
3. Make station adjustments to 360°
4. Make triangle adjustments to 180°
5. Adjust quadrilateral
6. Compute all sides
7. Solve for check base measurement & compare with actual.
8. In case where not possible to direct chain from pier to pier solve for α & β angles to locate.
9. Locate piers with angles if necessary. Best to use 2 instruments. Check location by sighting along ℄ Structure.
10. Proceed with referencing & construction layout to extent possible.

EXAMPLE

Angle	∠ x 1	∠ x 12	Average ∠
Transit @ Sta. A			
a	46° 07' 00"	553° 22' 00"	46° 06' 50"
b	53° 46' 00"	645° 13' 00"	53° 46' 05"
outside	260° 07' 00"	3121° 22' 00"	260° 06' 50"
Transit @ Sta. B			
c	48° 08' 30"	577° 40' 00"	48° 08' 20"
d	42° 17' 00"	507° 24' 00"	42° 17' 00"
Outside	269° 34' 30"	3234° 55' 00"	269° 34' 35"
Transit @ Sta. C			
e	35° 49' 00"	429° 50' 00"	35° 49' 10"
f	54° 03' 00"	648° 36' 00"	54° 03' 00"
Outside	270° 08' 00"	3241° 35' 00"	270° 07' 55"
Transit @ Sta. D			
g	47° 51' 30"	574° 15' 00"	47° 51' 15"
h	31° 59' 00"	383° 49' 00"	31° 59' 05"
outside	280° 09' 30"	3361° 54' 30"	280° 09' 32.5"

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FIGURE NO. 6

2. Locate the points for establishing the centerline of the structure. Make certain that the line and the stationing staked on the ground are in agreement with the plans.

3. Set two points on centerline of structure as near the two bridge ends as possible. These should be chosen to permit inter-visibility with all other triangulation points and to permit ready layout of substructure units.

4. Establish Base Lines - These should be chosen such that the base line and the check base line are nearly equal to the length to be measured and such that the interior angles of the triangles are approximately 60°. Where necessary, stake intermediate chaining points and supports. Be particularly careful to make intermediate chain points solid. Line points with transit. Provide supports at 20' intervals on straight line grade between intermediate chaining points. It is desirable to fasten a soft metal cap (aluminum) on the intermediate chaining points to permit scribing of lines for measurement rather than using tacks. Determine and record the elevation of the chaining points for calculation of slope correction when necessary.

5. Chain base line. A minimum of three measurements shall be taken on each base line. Personnel should be alternated so distance, temperature and tension are read by a different person for each complete base line measurement. Equipment necessary will include standardized chain, chain scale and chain thermometer. Record in notes chain tension, temperature and difference of elevation for each interval of base measured. Compute and apply temperature and slope corrections. Calculate probable error of base line. Consult a surveying text book for method of calculation.

6. Measuring angles - For accurate measurement of angles, the transit and targets must be centered over the points and stable supports used for the plumb lines or targets. Hand held plumb lines will not give acceptable results. Turn each interior and exterior angle at each triangulation point. When transit is used, turn each angle at least six (6) times with instrument direct and with instrument inverted to produce desired accuracy. See table below for example: (Table on following page)

No. of Repetitions	Limit of Possible Error
1	$\pm$ 0° 00' 30"
2	$\pm$ 0° 00' 15"
3	$\pm$ 0° 00' 10"
4	$\pm$ 0° 00' 07.5"
5	$\pm$ 0° 00' 06"
6	$\pm$ 0° 00' 05"

The precision with which the angle can be measured is not appreciably increased by repetitions in excess of 6. Use of KIAE theodolite will produce a limit of possible error of + 0° 00' 05" with a single reading.

7. Adjustment of Quadrilateral - The adjustment of observed angles of the quadrilateral is made in three steps: (1) The station adjustment, to make the sum of the angles around each point equal 360°, (2) the figure adjustment for the geometric condition that the sum of the interior angles of a rectilinear figure is equal to (n-2) 180°, in which "n" is the number of sides of the figure, (3) the trigometric condition that in any triangle the sines of the angles are proportional to the lengths of the sides opposite.

   a. Station Adjustment (Figure 7)

      Adjust the angles around each point to make their sum equal 360° by distributing the error equally (or approximately so) among the several angles.

   b. Figure Adjustment for Geometric Condition (Figure 8 & 9)

      When all angles in a quadrilateral are measured, there are four overlapping triangles. These are shown as triangles ABC, ACD, ABD, BCD in Figure 5. In each of these triangles the sum of the three angles must be 180°. Hence from the figures.

$$b+c+d+e = 180^{\circ} \qquad (1)$$

$$a+f+g+h = 180^{\circ} \qquad (2)$$

$$a+b+c+h = 180^{\circ} \qquad (3)$$

$$d+e+f+g = 180^{\circ} \qquad (4)$$

STATION ADJUSTMENT

Sta.	∠	Observed Value	Adjusted Value
A	a	46° 06' 50"	46° 06' 55"
	b	53° 46' 05"	53° 46' 10"
	Outside	260° 06' 50"	260° 06' 55"
	Sum	359° 59' 45"	360° 00' 00"
		$\frac{15}{3}$ = +5" Correction	
B	c	48° 08' 20"	48° 08' 22"
	d	42° 17' 00"	42° 17' 01"
	Outside	269° 34' 35"	269° 34' 37"
	Sum	359° 59' 55"	360° 00' 00"
		$\frac{5}{3}$ = +2" Correction	
C	e	35° 49' 10"	35° 49' 09"
	f	54° 03' 00"	54° 02' 58"
	Outside	270° 07' 55"	270° 07' 53"
	Sum	360° 00' 05"	360° 00' 00"
		$\frac{5}{3}$ = −2" Correction	
D	g	47° 51' 15"	47° 51' 18"
	h	31° 59' 05"	31° 59' 07"
	Outside	280° 09' 32.5"	280° 09' 35"
	sum	359° 59' 52.5"	360° 00' 00"
		$\frac{7.5}{3}$ = +2.5" Correction	

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FIGURE No. 7

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GEOMETRIC ADJUSTMENT

$\angle s$ $a+b+c+d+e+f+g+h = 360°$

a	46°	06'	55"
b	53°	46'	10"
c	48°	08'	22"
d	42°	17'	01"
e	35°	49'	09"
f	54°	02'	58"
g	47°	51'	18"
h	31°	59'	07"
sum	360°	01'	00"
	−360°	00'	00"
		01'	00"

$\frac{60"}{8} = 7.5"$ Correction

Corrected.

a	46°	06'	48"
b	53°	46'	02"
c	48°	08'	14"
d	42°	16'	54"
e	35°	49'	02"
f	54°	02'	50"
g	47°	51'	10"
h	31°	59'	00"

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FIGURE No. 8

GEOMETRIC ADJUSTMENT CONT.

$\angle s\ b + c = \angle s\ f + g$

b	53° 46' 02"	f	54° 02' 50"
c	48° 08' 14"	g	47° 51' 10"
Sum	101° 54' 16"	Sum	101° 54' 00"

16"/4 = ± 4" Correction

b	53° 45' 58"	f	54° 02' 54"
c	48° 08' 10"	g	47° 51' 14"
Sum	101° 54' 08"	Sum	101° 54' 08"

$\angle s\ d + e = \angle s\ h + a$

d	42° 16' 54"	h	31° 59' 00"
e	35° 49' 02"	a	46° 06' 48"
Sum	78° 05' 56"	Sum	78° 05' 48"

8"/4 = ± 2" Correction

d	42° 16' 52"	h	31° 59' 02"
e	35° 49' 00"	a	46° 06' 50"
Sum	78° 05' 52"	Sum	78° 05' 52"

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FIGURE No. 9

Also the sum of the eight lettered angles in the figure must equal 360°, since they form the interior angles of a closed figure of four sides.

$$a+b+c+d+e+f+g+h = 360^{\circ} \quad (5)$$

Further since the opposite angles at the intersection of the diagonals must be equal, it follows that:

$$b+c = f+g \quad (6)$$
$$d+e = h+a \quad (7)$$

If any three of these seven equations are satisfied, the other four must of necessity be satisfied also. Equations (5), (6) and (7) are the ones most convenient to use.

1. Using the values resulting from the station adjustment, add the eight angles, a, b, c, d, e, f, g and h and subtract their sum from 360°. Divide the difference by 8, and algebraically add the result to each of the eight angles, thus satisfying the conditions of equation (5).

2. Using the adjusted values from "1", find the difference between the sums (b+c) and (f+g) and divide that difference by four. Apply the results as a correction to each of the four angles, increasing each of the two whose sum is the smaller and decreasing each of the two whose sum is the larger, thus making these angles satisfy equation (6) without disturbing the adjustment for equation (5). Proceed in the same way for each of the four angles involved in equation (7).

c. Figure Adjustment for Trigometric Condition (Figure 10)

If the length of one line, as AB, is known, and the length of the opposite side CD is to be computed, the computer may select one or another series of triangles for use in accomplishing this result. For example, a solution of triangle ABC gives the length of AC, then from triangle ACD the required length of CD is found; or in the triangle ABC the length BC is found, then in BCD the length CD is computed. There are four possible choices of route through the figure. It now remains to be seen whether the angles, as so far adjusted, are so related as to make the value of the length of a computed side independent of the route used.

TRIGONOMETRIC ADJUSTMENT

log sin	a	46° 06' 50"	9.857768	2
	c	48° 08' 10"	9.871998	2
	e	35° 49' 00"	9.767300	3
	g	47° 51' 14"	9.870075	2
sum			9.367141	
log sin	b	53° 45' 58"	9.906666	2
	d	42° 16' 52"	9.827862	2
	f	54° 02' 54"	9.903221	2
	h	31° 59' 02"	9.724017	3
sum			9.366766	18

$9.367141 - 9.366766 = 375$

$375/8 = 47 = X$

$18/8 = 2.25 = Y$

$\frac{X}{Y} = \frac{47}{2.25} = 21''$ Correction

Final ∠s to be used for Computations

a	46° 06' 29"	b	53° 46' 19"
c	48° 07' 49"	d	42° 17' 13"
e	35° 48' 39"	f	54° 03' 15"
g	47° 50' 53"	h	31° 59' 23"

FIGURE NO. 10

Assume that the length of AB is known and the length of CD is to be found.

$$AD = AB \frac{\sin c}{\sin h}$$

$$CD = AD \frac{\sin a}{\sin f} = AB \frac{\sin a \sin c}{\sin f \sin h} \quad (8)$$

Similarly,

$$CD = AB \frac{\sin b \sin d}{\sin e \sin g} \quad (9)$$

Equating these two values of CD,

$$\frac{\sin a \sin c}{\sin f \sin h} = \frac{\sin b \sin d}{\sin e \sin g} \quad (10)$$

Or

$$\frac{\sin a \sin c \sin e \sin g}{\sin b \sin d \sin f \sin h} = 1 \quad (11)$$

Expressed in logarithims form, this is

$$(\log \sin a + \log \sin c + \log \sin e + \log \sin g) - (\log \sin b + \log \sin d + \log \sin f + \log \sin h) \quad (12)$$

The angles are tested for satisfaction of this equation by adding the logarithmic sines in the two groups as indicated and by finding the difference between the two sums.

A simple approximate method of adjustment which gives an equal correction to each angle and does not disturb the geometric condition is as follows: (See adjustment in the example as shown)

a. Record the log sines as shown in the example.

b. For each angle, record the tabular logarithmic sine difference for 1" opposite each logarithm.

c. Find the average required change (x) in log sine by dividing the difference between the sums by 8.

d. Find the average difference (y) for 1".

e. The ratio x/y gives the number of seconds of arc to be applied as a correction to each angle.

f. Add this correction to each of the four angles the sum of whose log sines is the smaller, and subtract it from each of the angles the sum of whose log sines is the larger, and thus the corrected values are obtained.

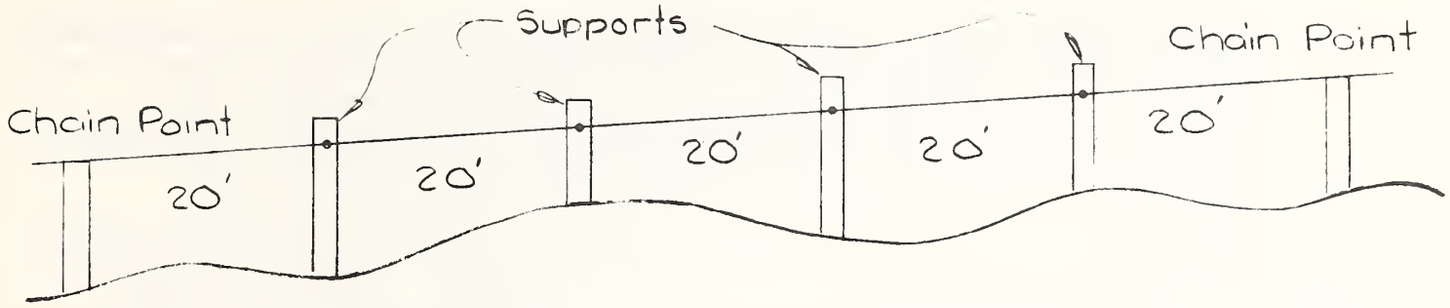
8. If the computed length of the check base line compares to the measured length within the prescribed limits of error, proceed with the layout of the substructure units. This preferably should be done from the two points previously set on the centerline, in accordance with the procedures for direct chaining. Referencing of substructure units and checking of span lengths should be accomplished as described previously to the greatest extent possible. If direct chaining is not permissible, location of substructure units can be accomplished by triangulation as shown on Drawing No. 5. Angles are calculated and turned from each base line for each point required. Angles used for this purpose must be greater than 6°. The functions of angles of less than 6°, in tables generally used for calculation, are not sufficiently accurate to permit calculation of the angle to the required precision. It is extremely important to reference triangulation points to permit accurate re-establishment at any time.

35.07 General Information - Horizontal Control

1. Chaining - The following are the effects various factors have on chaining:

Factor	(The Deviations Below Will Cause an Error of 0.01 per Chain Length)	(Makes Chain)
Temperature	15° F.	Long or Short
Tension	15 Lb. (1½ lb. chain)	Long or Short
Slope	1.4 Ft.	Short
Horizontal Line	1.4 Ft.	Short
Wind	0.6 Ft. Bow in Center	Short
Plumbing (Breaking Chain on Steep Slope)	0.5' to 0.10' per 100' Chain Length	Long or Short

SLOPE CHAINING



1. Standardize chain for the condition shown.
2. Set stakes on line with transit.
3. Record elevations on top of stakes at ends of chain interval.
4. Place nails for chain support in intermediate stakes on straight line grade between end stakes.
5. Fasten securely to top of end stakes a strip of copper, lead, aluminum or other soft metal that can be scribed.
6. Pull chain to proper tension. Rear chain on scribe mark. Head chain scribes mark.
7. Record temperature

RELATIONSHIP OF ANGULAR TO LINEAR ERROR

ANGULAR ERROR	LINEAR ERROR in 1,000 Ft.	RATIO OF ACCURACY
0° 10' 00"	2.9089	1/344
0° 05' 00"	1.4544	1/688
0° 01' 00"	0.2909	1/3,440
0° 00' 30"	0.1454	1/6,880
0° 00' 20"	0.0970	1/10,300
0° 00' 10"	0.0485	1/20,600
0° 00' 05"	0.0242	1/41,200
0° 00' 01"	0.00484	1/206,600

FIGURE No. 11

2. Measurement by chaining slope distance, measuring vertical angle, and computing horizontal distance. The accuracy of this method is limited to the accuracy to which the vertical angle can be determined in addition to the above factors. In the case of a transit with a one minute vernier on the vertical circle, the following is an example:

Vertical Angle	Probable Limits of Error in Ft. per 100 Ft.
20°	+ 0.01 to - 0.01'
30°	+ 0.01 to - 0.01'
45°	+ 0.02 to - 0.02'

It is important that correction be made for the index error of the instrument when measuring the vertical angle.

3. Setting of Points. The following factors should be considered in choosing materials and methods for survey points.

   a. Length of expected need. Do not expend a lot of effort in setting points required for a short time. Points to be retained for long periods such as triangulation stations and primary control references will justify the expenditure of extra effort as replacement is costly.

   b. Stakes. These can include the usual 2" x 2" hubs, iron pins, 2" x 4" stakes, etc. Iron pins and 2" x 4" stakes should be a minimum of 18" long. In general drive them flush with the ground. Soil conditions, both present and expected future, will normally determine the type of stakes. If unusual conditions are encountered, acquisition of materials other than what is normally supplied is justified as each point represents a considerable investment in time and money.

   c. Guard Stakes. Clearly identified the point on the guard stakes and replace as required. It is suggested for further protection in addition to the guard stakes, a 2" x 4" x 4' or 4' steel bar with a large cloth flag be driven securely in place to protect the primary control points. DO NOT USE FLAG NEAR RAILROAD OR IMMEDIATELY ADJACENT TO P.T.W. Check with railroad authorities before placing any stakes, lath, etc. on railroad right of way. Any type of flag is generally unacceptable to them.

d. Iron pins are generally used for bench marks. Leave top approximately 1" above ground. In some cases, it may be necessary to place concrete around pin to prevent settlement or displacement.

35.08 Vertical Control - Bench Marks

Plan locations of bench marks to permit control of the work with the least amount of turns. Locate bench marks in areas where they will not be disturbed or subject to settlement and are readily accessible.

1. Locate in the field at least three of the bench marks shown on the plans.

2. Establish points for bench marks needed in the vicinity of the structure. A minimum of two are required. Do not locate bench marks on newly placed fills; in areas subject to movement from frost action, slides, etc. or on superstructures of existing bridges. Also avoid areas near edges of fill as these are subject to displacement from weight of fill.

3. Check adjustment of level.

4. Beginning at a bench mark shown on the plans, run levels through the bench marks set for the structure to a second and third bench mark shown on the plans and close the circuit back to the point of beginning. Attempt to balance backsight and foresight distances. Turn through each and every bench mark. Bench mark elevations set by side shots are of no value and have no place in bridge construction surveys. Use reciprocal leveling procedures for long river crossings or other situations where length of foresight exceeds 300'.

35.09 Vertical Control - Construction Grades

1. General. It is good practice to utilize at least two bench marks in setting or checking construction grades. This will detect possible settlement of bench marks as well as calculation and observation errors.

2. The following are the limits of permissible error for various units of structure: (Listed on following page)

Point or Portion of Structure	Limit of Permissible Error
Bench Mark	$\pm 0.05' \sqrt{\text{Distance in Miles}}$
Footing X-Section	±0.05' of Plan Elevation-Nearest 0.1'
Footing Cut Stake	±0.02' of Plan Elevation-Nearest 1/4"
Footing Elevation	±0.02' of Plan Elevation-Nearest 1/4"
Column Elevation	±0.02' of Plan Elevation-Nearest 1/4"
Top of X-Beam	±0.01' of Plan Elevation-Nearest 1/8"
Beam Seat, Structural Steel Splices, Curbs, Deck Slab Forms	±0.01' of Plan Elevation-Nearest 1/8"
Beam 10th Point, Top of Deck, Guard Angle, Expansion Joints	±0.005' of Plan Elevation-Nearest 1/16"

3. Structure Excavation Cross-Sections. Take sufficient number of shots to permit quantity calculations to be made. Precision required for shots - nearest 0.10'.

4. Set stakes showing cut to bottom footing. Rod read to nearest 0.01' and cut shown to 0.01'. Indicate on stake from where cut is to be measured.

5. Check to see grades for footing and column forms have been set to within 1/4" of plan elevation.

6. Grades for tops of crossbeams and beam seat should be within 1/8" of plan elevation.

7. A rod level should be used in cases where it is necessary to use a high rod and where waving the rod is not possible or practical.

8. Turning points should be chosen or set that will not settle between foresight and backsight.

9. In checking and setting grades for construction, it is very desirable to take check shots on points of known elevation of other units of structure already completed.

35.10 Fill Settlement Check Elevations

Whenever the sequence of work calls for a specific settlement period to elapse after the roadway embankment is completed, there is no guarantee that the settlement will occur or be completed by the end of the specified time. It merely allows the fill a period of time in which the major part of the expected settlement or con-

solidation can occur. The following steps should be taken whenever settlement elevations are being established and shall start immediately upon completion of the fill at the bridge end. (See Figure No. 12 for typical installation).

1. Establish enough points so that if several are destroyed, sufficient points are left to complete the record.

2. Set some of the points in positions where they are not likely to be destroyed by necessary operations.

3. Tie levels between two established bench marks; do not depend on one as it can be affected by settlement of nearby fill.

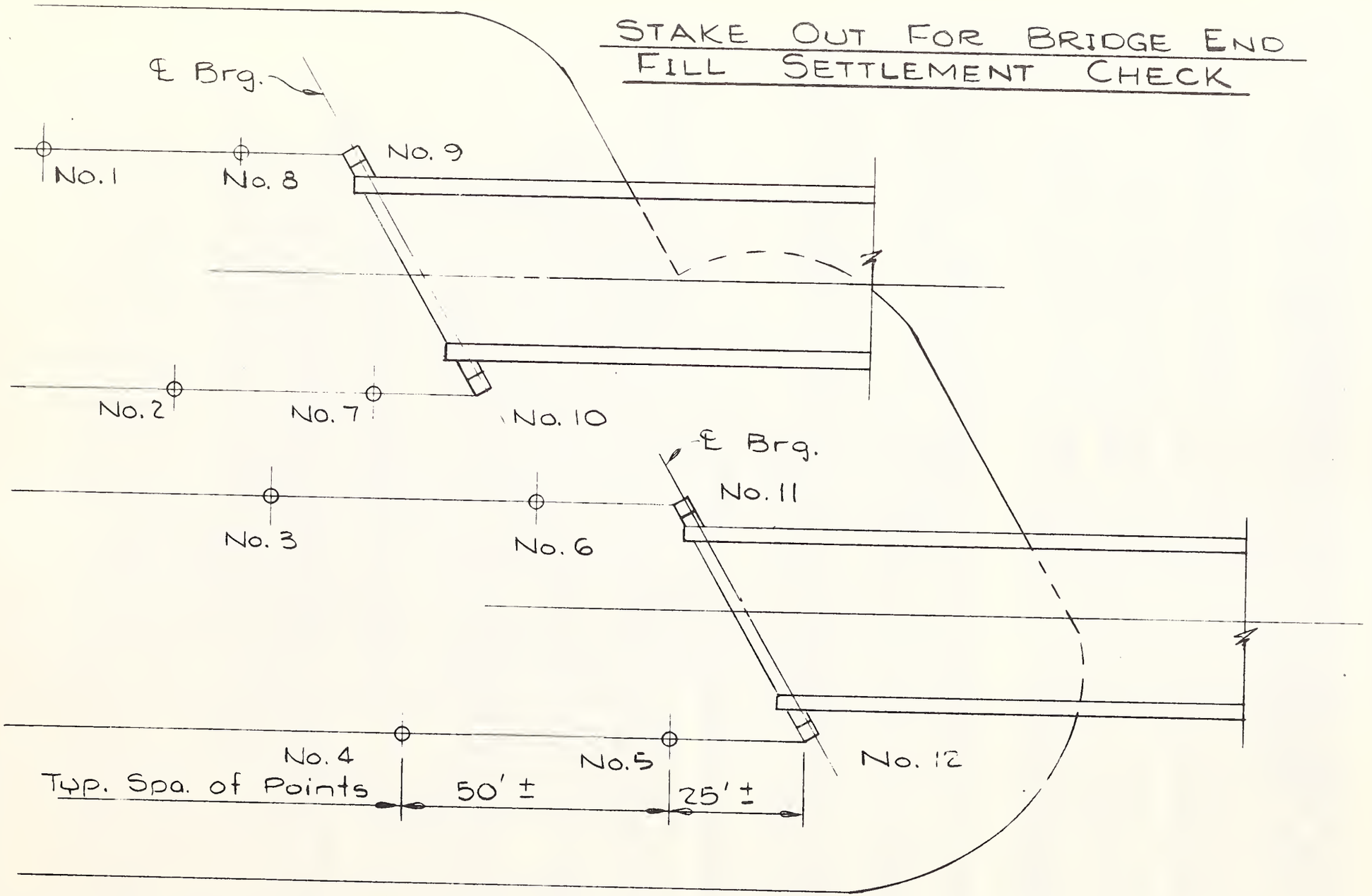
4. Take and record readings at least once a week. When three or four weeks pass with no movement noted, this may be reduced to once every second week. Submit copies of all readings to the Construction Bureau.

With an accurate record available for review, it may be possible that a portion of the stipulated fill settlement period may be waived. If settlement is still occurring at the end of the specified period, full details should be submitted for review.

35.11 Structure Settlement Check Elevations

Whenever structure settlement is noted on completed items of work, the Construction Bureau should be notified immediately and a settlement record system started. This will be done by establishing permanent marks on or over the substructure units by marking an X on the guard angles, floor joints or concrete near the face of both curbs and on centerline at each and every bent or pier. Take and record readings at least once a week until three or four weeks pass with no movement noted. Then continue readings every second week until you are satisfied settlement has ended. Submit copies of field records to the Construction Bureau. You will be advised as to the corrective action to be taken. Place bench marks on the ends of all newly placed caps of bents and piers and record the elvations to the nearest 0.01'. This must be done as soon after the concrete is placed as practical. This will provide information as to whether differences in elevations that may be noted later are due to settlement or are due to a possible error in elevation during construction. If the difference in elevation is actually due to settlement, it is important to know if it took place rapidly or slowly and if it is still occurring.

STAKE OUT FOR BRIDGE END FILL SETTLEMENT CHECK



Note: Establish and use Bench Marks which are sufficient distance from the fill area so that their accuracy will not be affected by any settlement or consolidation which takes place under the fill.

FIGURE No. 12

35.12 Structures Involving Railroads

1. On railroad grade separation work, the stationing of the mainline tracks or other railroad reference line shown on the plans should be carefully checked to assure that proper lateral clearances will be provided.

2. The first step in locating a structure over a railroad is to establish the point where the centerline of roadway or centerline of structure intersects with the centerline of the Mainline Tracks. The rest of the structure will be layed out from this point disregarding any discrepancy in roadway stationing of structure units.

3. Take elevation on top of rail at sufficient locations in vicinity of structure to assure proper vertical clearance is provided. This information is also helpful for shoring and cribbing plans and in case a question arises over the effect construction activities are having on the tracks.

4. The following are some precautions to be observed in stake-out near or on railroads:

   a. Watch for trains.

   b. Do not allow steel chain to drop across tracks. This will lead to an unpleasant visit from railroad officials in a very short while.

   c. Do not allow chain or other equipment to come in contact with trolley wires, high tension wires, etc. This will lead to the need for a NEW SURVEY CREW.

35.13 Management of Engineering Control Surveys

Good management practices are equal in importance to good engineering practices in reducing costly engineering control errors in bridge construction.

A. General

Layout and engineering control of bridges requires precision not necessary nor generally practiced on most other highway construction. This is due mainly to the materials used in the construction of bridges. Once concrete is in

the forms and hardened, correction of any mistakes is very costly and time consuming. Errors in span lengths, column lengths, cap elevations, etc. generally require costly modifications to be made. Very probably Federal participation in these modifications will be limited or non-existent. For the reasons given, it is necessary that every effort be made to provide this precision.

B. Assignment of Personnel

IT IS DESIRABLE TO ASSIGN THE SAME PERSONNEL TO STAKING WORK WHO WILL BE ENGAGED IN THE ENGINEERING CONTROL AND INSPECTION OF CONSTRUCTION FOR THE PROJECT. It is generally accepted that more interest is shown and more care is taken in survey work when a person knows that he is going to be responsible for construction of the facility for which the survey is being made. Work of new or temporary personnel or permanent personnel new to bridge work should be carefully observed. Any personnel who cannot or will not work with accuracy required cannot be tolerated on bridge work due to high costs of correcting structure errors.

C. Time Allowed for Staking

It is imperative to allow sufficient time for checking plans, staking, referencing, and checking of primary controls for the structure prior to the beginning of construction work. Consideration must be given to expected weather conditions, availability of points, terrain, required accuracy of survey, etc.

On multiple structure projects, it is desirable to allow time sufficient for establishing primary controls for all structures as this permits establishing of construction controls with a minimum of time and effort and frees personnel for inspection duties during construction. The practice of delaying establishment of controls to the last minute or of the project personnel arriving on the project at the time the contractor is ready to begin work leads to a choice between two unacceptable alternatives:

1. Suspend contractor's operations until staking, checking and referencing are complete. The Federal Highway Administration does not recognize this as a legitimate reason for suspension of work and will assess the State liquidated damages if contract time overruns.

2. Provide only minimal staking without proper referencing and staking to allow work to begin. Too often the second alternative results in very costly errors. Proper management and planning can eliminate the need for making this choice.

D. Equipment

Equipment capable of producing the required accuracy must be made available and used. The precision required for bridge construction survey controls justifies the use of more sophisticated equipment than is normally used on highway work.

Layout of engineering controls is generally a major expense in construction engineering costs. The use of equipment that will provide the necessary accuracy with less time expended can help reduce these costs. For primary control system staking for a structure, it is highly desirable that a theodolite be made available. For long span steel structures or situations involving triangulation from base lines where permissible error is less than 1 in 10,000, its use is practically mandatory. The following is a list of major survey equipment necessary for structure layout.

1. Project

Minimum - Transit in excellent condition; chain - checked against standard and standardized for all expected conditions of use; level - automatic, in good condition.

2. Division Office

Standard chain for comparision and standardizing of chains in the field. Upon request, arrangements can be made with the Montana State University Civil Engineering Department to compare a new chain against a standardized Lovar chain. One such new chain per Division should be available for comparison with chains used in the field.

E. Project Management of Engineering Control

1. Review and check plans prior to beginning staking. Do not grab plans, head for a structure and begin staking as soon as you come on a project just to keep everyone busy. This can and very often does lead to costly errors and aggravating duplication of work. All personnel should at least have an opportunity to review plans and become familiar with construction details affecting layout.

2. Plan layout and referencing to keep duplication of work to a minimum. The time spent on planning, prior to layout, will save valuable time during construction. For instance - it is not reasonable to make layout of footing centerlines, etc. in areas where channel excavation must be removed prior to bridge work.

3. Make contractor, and particularly the superintendent, aware of their specified responsibility in the preservation of control points. Advise of the possible cost and time necessary for replacement. Also advise that should it become necessary to remove or disturb a point to allow construction operations, prior notification is required. This should be discussed at the Pre-construction Conference.

   Prior to staking of controls in the immediate construction areas, consult with contractor's personnel in charge of work to determine convenient locations not subject to disturbance for the period they are required. Make it understood that these are being placed for his use with the intention that it will be done one time only.

   In cases where continual careless, or willful destruction of control points occurs, action should be taken to prevent expensive, time consuming replacement. It is not unreasonable to expect that sufficient care be taken so as not to disturb a small area around a 2" x 2" hub. Actions that can be considered and are allowable under the Specifications include deduction of the expense of replacement from the contractor's estimate and the removal of uncooperative contractor personnel from the project.

4. It is desirable that the contractor furnish a proposed schedule of operations and keep it current to allow determination of manpower and equipment needs for timely staking.

5. Notice should be given by the contractor for checking of forms, etc. sufficiently in advance to permit timely checking and efficient utilization of project personnel. Procedures for this should be established at the beginning of construction.

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4. It is desirable that the contractor furnish a proposed schedule of operations and keep it current to allow determination of manpower and equipment needs for timely staking.

5. Notice should be given by the contractor for checking of forms, etc. sufficiently in advance to permit timely checking and efficient utilization of project personnel. Procedures for this should be established at the beginning of construction.

F. Impress on project personnel the need for constant checking of the work. Make every effort to keep them aware of this need throughout the time of construction. Rough checks that take very little time or effort, visual comparison of column heights to approach fills and other bents, taping between like units on separate bents, can and have disclosed gross errors in design or layout and prevented costly extra work. The elimination of errors is mainly dependent on constant checking.

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